STATE OF UTAH

Urban and Suburban Stormwater Management Plan

An addendum to the:

UTAH NONPOINT SOURCE MANAGEMENT PLAN

March 2013

Prepared for:
UTAH WATER QUALITY TASK FORCE

In Cooperation with:
The Utah Department of Environmental Quality
And the University of Utah

Utah Department of Environmental Quality

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Chapter 1: Overview

Introduction

This document addresses the urban and suburban stormwater component of the Utah Nonpoint Source Management Plan. It provides guidance for stormwater managers faced with mitigating pollution and/or providing runoff control. This document also provides stormwater best management practice (BMP) sizing guidelines to enhance stormwater control for water quality beyond traditional quantity control design process. Fact sheets for 31 BMPs are included to provide an overview of the options available for stormwater runoff control.

Chapter 1 of this document provides background information for the diffuse urban and suburban nonpoint sources, including storm water runoff, construction activities, waste disposal systems, and roads components. This chapter also provides background on the non-structural and structural mitigation efforts available via stormwater BMPs. Chapter 1 also provides and overview of potential sources of funding for stormwater management. Specifically, it considers the grants made available under Section 319 of the Clean Water Act and other sources of support.

Chapter 2 of this document describes the State of Utah's control strategy for stormwater management. Goals and objectives for diffuse urban and suburban pollution sources are summarized, and indexes are provided for evaluating the success and/or progress of the NPS stormwater program in the State of Utah. Control measures necessary to achieving the stated goals and objectives are also identified.

Chapter 3 of this document provides an overview of the DESIGN GUIDELINES. This chapter also provides a BMP Design Analysis Tool, which is composed of simple flow diagrams representing the specific BMPs that are most applicable to the given the constituents and/or environmental conditions present.

Chapter 4 of this document describes how to measure the success of the Utah NPS Plan components, highlighting the use of "adaptive management," which is a cycle of assessments, planning, implementation, and monitoring.

Appendix A provides an overview of recommended BMPs for stormwater control in developing and redeveloping areas; fact sheets are provided for each BMP type listed in Table 1. It should be noted, however, that Appendix A does *not* provide all of the necessary specifics required for the following actions associated with BMPs such as design and construction details or maintenance and management plans. Each fact sheet provides numerous external sources to provide additional information for these aspects. Design, construction, and maintenance should be completed under the supervision of and in cooperation with the necessary groups and professionals.

Table 1. BMP Fact Sheet Topics in Appendix A

Capture, Retention, Detention	Filters, Flow Control, Separators	Impervious Surface Reduction
Soil Erosion Control	Surface Sand Filter	Street Design
Constructed Wetlands	Underground Filter	Cul-de-Sac Design
Retention Systems	Oil/Grit Separator	Driveway Design
Detention Systems	Check Dams	Parking Lot Design
Dry Swales	Dikes, Berms, Swales	Turf and Permeable Pavement
Rainwater Harvesting	Proprietary Flow Control Devices	Green Rooftops
Bioretention		Minimization of Clearing and Land Disturbance
Infiltration Enhancement	**Management**	**Vegetative Measures**
On-Site Infiltration	Pavement Management	Filter Strips
Infiltration Basins	BMP Maintenance	Aquatic Buffers
Infiltration Trenches	Animal Management	Erosion Control
		Vegetative Stabilization
		Landscape Design and Maintenance

Background

The hydrologic effects of urbanization are well known by watershed engineers and scientists. When a watershed is developed, the land is covered with impervious surfaces such as roads, parking lots, roofs, driveways, and sidewalks. These impervious surfaces restrict the amount of water that is allowed to infiltrate into the ground and increase the amount of surface runoff, both of which work in combination to alter the natural flow regime of the system. Nine case studies compiled by the United States Environmental Protection Agency (1997) document the hydrological effects of urbanization, including: increases in bankfull events, increased flooding, increased peak flows, decreased baseflow, stream enlargement, stream incision, severe stream bank erosion, sedimentation, changes in morphology, increased instream sediment load, increased sediment transport, aesthetic degradation, degradation of designated uses, and loss of fish populations. Roesner and Bledsoe (2003) summarize the fundamental hydrologic changes that are associated with urbanization as: (1) more frequent and higher magnitude flows; (2) increased duration of geomorphically significant flows; (3) flashier/less predictable flows; (4) altered timing and rate of change relative to riparian and floodplain connections; (5) altered duration of low-flow periods; and (6) conversion of subsurface distributed discharge inputs to surface (point) discharge.

Peak-flow increases from two- to more than 50-fold typify the changes brought by urbanization (Hollis, 1975; Urbonas and Roesner, 1992; Roesner, et al., 2001). Hollis (1975) showed patterns of increasing change in peak discharge with increasing percentage of impervious area and decreasing storm magnitude. Using 50 years of hourly rainfall records, Nehrke and Roesner (2004) showed that flow exceedance frequencies increased dramatically when development of a watershed was left uncontrolled. Nardi and Roesner (2003) showed that flow durations for small discharges increased significantly when uncontrolled development took place, and that the addition of extended detention best management practices produced the greatest increase in the flow duration curve.

Nonpoint Source Pollution

Nonpoint source pollution typically involves land runoff, precipitation atmospheric deposition, drainage, seepage, or hydrologic modification of an area. A nonpoint source of pollution is, by definition, any source of water pollution that does not stem from a point source, as detailed in section 502(14) of the Clean Water Act. Under this law, a point source is defined as:

The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

The medium of nonpoint source pollution, especially in the state of Utah, is either rainwater or snowmelt runoff. This pollution increases as it moves across the urban landscape and enters the hydrologic cycle via infiltration (ground water) and unchecked return flows to the receiving environment, such as rivers, creeks, and streams (surface water) (EPA, 2010).

Diffuse Urban and Suburban Sources

The pollution resulting from urban and suburban sources is generated by a broad range of activities associated with domestic, municipal, industrial, and commercial land development and land use. Mitigation of urban and suburban pollution sources presents challenges since the associated infrastructure, once in place, may be present permanently and may have long-lasting impacts on the water resources.

Storm water runoff, construction projects, stream channelization, waste disposal, road sanding/salting, and daily household activities possess the potential of being significant sources of NPS pollution. Fertilizers, pet wastes, leaves, grass clippings, and faulty septic tanks can contribute to nutrient and bacterial pollution. Improperly handled chemicals, paints, solvents, detergents, antifreeze, and pesticides may also enter water systems. Landfills, particularly those that are unlined, pose a threat to surface and ground water quality due to the potential for the leaching of harmful and toxic substances into aquifers and surface waters. Roads can be a source of petroleum hydrocarbons and heavy metals from diesel and gasoline vehicle usage and even road maintenance activities, such as sanding and roadside vegetation management, can contribute sediments, pesticides, and nutrients to adjacent waterways (Montana Nonpoint Source Management Plan, 2007). For a graphic representing the effects of urbanization on streamflow, see Figure 1.

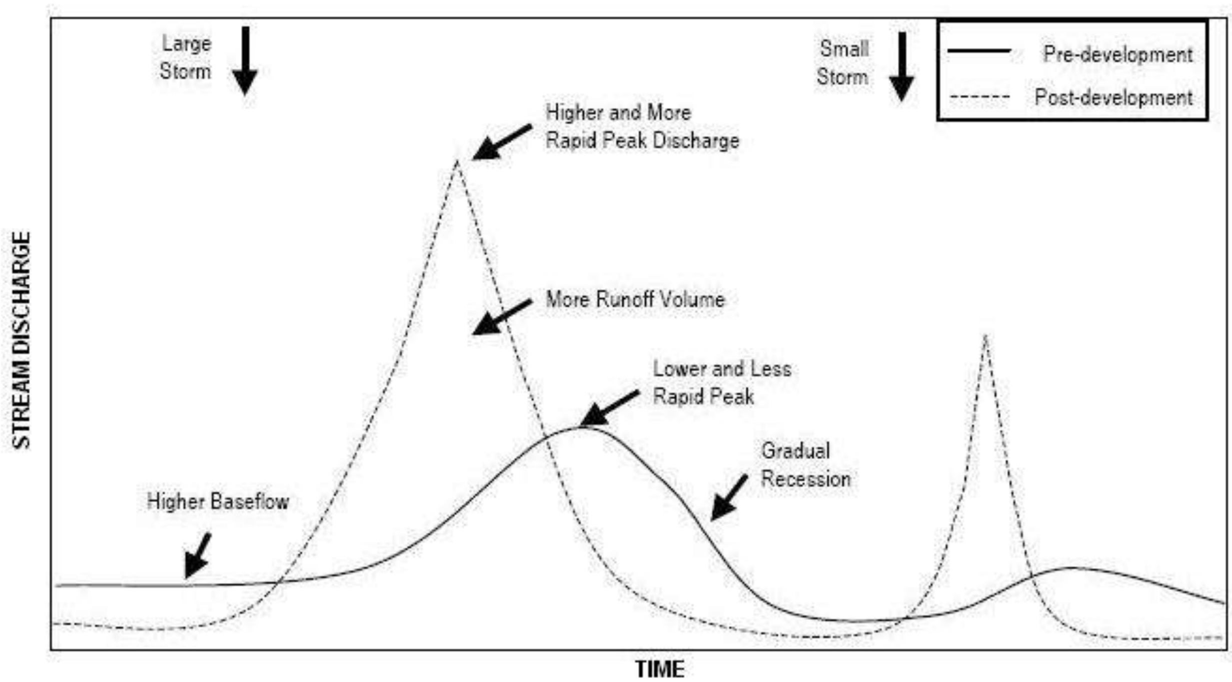

Figure 1: Changes in Streamflow Hydrograph as a Result of Urbanization (*National Management Measures to Control Nonpoint Source Pollution from Urban Areas*, 2005, U.S. EPA, EPA-841-B-05-004, page 0-23.)

Storm Water Runoff

Buildings and infrastructure, such as roads, sidewalks, and driveways, generally possess higher amounts of impervious surfaces, which prevent water from soaking into the ground and, as a result, leads to increased generation of runoff. Urban, suburban, and construction site storm water runoff are principal sources of NPS pollution (Montana Nonpoint Source Management Plan, 2007). Storm water runoff resulting from urban surfaces are a "leading threat to water quality, and the percentage of impervious surface within a particular watershed has been recognized as a key indicator of the effects of nonpoint runoff and of future water and ecosystem quality (Arnold and Gibbons, 1996; EPA, 1994).

Storm water runoff may carry high levels of pollutants, including:

- Sediments
- Oil, grease, and toxic chemicals from motor vehicles
- Pesticides and nutrients from lawns and gardens
- Viruses, bacteria, and nutrients from pet waste and failing septic systems
- Road sand and salt
- Heavy metals from roof shingles, motor vehicles, and rooftops
- Thermal pollution from dark impervious surfaces such as streets and rooftops

The type and concentration of pollutants in storm water runoff is highly variable and can harm fish and wildlife populations, kill native vegetation, foul drinking water, and make recreational areas unsafe and unpleasant (EPA, 2010). The frequency and intensity of precipitation directly affects the amount of pollutants collected in overland flow, the distance the pollutants are transported, and the level of sediment deposition and suspension. Impervious surfaces (i.e. streets, driveways, parking lots, sidewalks, roofs, et cetera) act as collectors and conduits for pollutants resulting from concentrated human activities until storm water runoff transports them, untreated, into waterways via storm sewer systems. When left uncontrolled, these discharges can threaten public health, kill aquatic organisms, destroy sensitive habitats, and contaminate drinking water supplies (Montana Nonpoint Source Management Plan, 2007).

Construction

Suspended sediments constitute the largest pollutant loads to receiving waters in urban areas, with construction serving as a leading cause of erosion. Typically, sediment runoff rates from construction sites are 10-20 times greater than those from agricultural lands and 1,000 to 2,000 times greater than those of forested areas. During a short period of time, construction activity can contribute more sediment to streams than is naturally deposited over time.

In addition to direct water quality impacts, construction and associated land development often changes the hydrology and geomorphology of receiving waters, with potentially adverse effects on aquatic and riparian habitats. Development reduces vegetative cover and increases the surface area of impervious surfaces, thereby disrupting the natural hydrologic cycle. As the impervious surface increases, the volume and intensity of runoff synthesized during rain events increases. The resulting stream flows can lead to channel widening, erosion, decreased channel stability, stream temperature increases, and sediment suspension and deposition. Over time, these effects may adversely impact aquatic life, water quality, and associated recreational activities. With pollutant contributions also increased, the magnitude of negative impacts is greatly expanded. National and local studies have shown that when as little as eight to twelve percent of a watershed surface consists of impervious surfaces, aquatic life is adversely impacted (EPA, 2005; Montana Nonpoint Source Management Plan, 2007).

Waste Disposal

In the United States, septic systems comprise the largest contribution of impaired waters to soils and ground water and, thus, have been linked to water quality degradation. These systems are also referred to as on-site subsurface wastewater treatment systems.

A properly maintained septic system can treat and, in some cases, completely remove contaminants from wastewater; however, several optimal conditions must first be met in order to avoid the release of excess pollutants to ground water and, ultimately, surface water. Associated with septic systems, common pollutants of concern include: nutrients (nitrogen and phosphorous), pathogens (bacteria, parasites, and viruses), household chemicals, personal care products (pharmaceuticals), and resultant byproducts (endocrine disrupting chemicals) (Montana

Nonpoint Source Management Plan, 2007). Even under properly functioning conventional designs, septic systems are capable of releasing fairly high amounts of nitrogen, in the form of nitrate, which is "becoming a ubiquitous problem, particularly in rural and suburban areas where domestic water supplies are obtained from individual on-lot water supply wells" (Hagerty & Taylor). In the United States, septic system failure rates are estimated to range from 5 to 25 percent and higher (EPA, 2005). Accordingly, periodic maintenance and inspection are crucial for preventing septic system failure.

Roads

The state's transportation systems contribute greatly to NPS pollution, via storm water runoff, construction sites, maintenance activities, flood plain encroachment, and atmospheric deposition. Vehicles consistently release pollutants to the environment, such as oil and grease, particulate matter, and heavy metals (i.e. regular brake pad wear and tear), which can be picked up by storm water runoff and conveyed to receiving water bodies. In addition to runoff concerns, road construction may result in the constriction of flow at road crossings (including culverts and bridges), soil erosion, and head-cutting, all of which increase sediment loads and may also contribute to in-stream and riparian habitat modifications. Maintenance activities, such as roadside vegetation management and road sanding, can unintentionally contribute pesticides, sediment, and chlorides (via traction and deicing chemicals) to water bodies. Vehicle exhaust (nitrous oxides, particulates, lead, et cetera) contributes to air pollution and can affect water quality through atmospheric deposition (Montana Nonpoint Source Management Plan, 2007).

Best Management Practices (BMPs)

BMPs are applications that are designed to provide mitigation of pollution resulting from diffuse sources, such as those stemming from the urban and suburban sectors. BMPs are both technology- and education- based, with the goal of reducing contamination to the Maximum Extent Practicable (MEP). BMPs represent the operational activities, physical controls, or educational measures that are applied to reduce the discharge of pollutants and minimize potential impacts upon receiving waters. This approach includes both structural and non-structural practices, which have direct impacts on the release, transport, or discharge of pollutants (Field, 2004). A listing of such BMPs can be found in Appendix A.

In order to effectively diminish the adverse impacts associated with urban and suburban developments, integration and implementation of BMPs into the urban and watershed framework is necessary.

Low Impact Developments (LIDs)

Low impact development is an alternative, ecologically-sensitive design approach that imitates the processes that natural areas store and infiltrate rainwater. LID is a relatively new concept in the United States, first gaining momentum in Maryland in the 1990's (LID Center), but such practices are becoming the more sustainable and effective options to choose from. The LID approach protects local and regional water quality by decentralizing storm water conveyance and mitigating negative rainfall impacts throughout the urban landscape. LID consists of storm water management practices that can be incorporated within smart growth and/or green building strategies. However, LID techniques mainly focus on the hydrologic and ecologic impacts of site-specific development, with greater attention paid to quality control (Montana Nonpoint Source Management Plan, 2007). The objectives of LIDs are accomplished by:

- Minimization of storm water impacts to the MEP, via reduction of imperviousness, conversation of natural resources and ecosystems, maintenance of natural drainage courses, reduction in the use of pipes, and minimization of clearing and grading
- Providing storage of storm water runoff uniformly throughout the site's landscape, with a variety of detention, retention, and runoff practices, highlighting the enhancement of water quality aspects
- Maintaining or reestablishing predevelopment time of concentration by strategically routing flows, in order to maintain travel time and control the discharge
- Implementation of effective public education programs to encourage property owners to use pollution prevention measures and maintain the on-site hydrologically functional landscape management practices

Such actions are effective when uniformly spread or strategically integrated across the urban landscape (Prince George's County, 2000).

LID involves both structural and non-structural practices that aim to treat storm water as close to the source as possible. In doing so, this helps decrease the extent and cost of additional, downstream mitigation efforts. The basic idea of LIDs is to promote storage, infiltration, and ground water recharge, via storm water retention and detention areas, reduction and disconnection of impervious areas, and extending the flow paths and runoff (lag) times. Structural LID practices include bioretention facilities or rain gardens, grassed swales, soil amendments, vegetative roof covers or green roofs, permeable pavements, rain barrels and cisterns, and tree box filters. Non-structural LID practices include planning and management actions, such as the preservation of ecologically-sensitive areas (riparian corridors, mature trees, steep slopes, et cetera), disconnecting rain gutters from the storm sewer systems, and minimizing impervious surfaces (i.e. shared driveways).

LID practices require site-specific design and maintenance, but case studies exhibit an overall savings of 25 to 30 percent over conventional residential building techniques (LID Center). Cost savings and increased aesthetics provided by incorporating landscaping are incentives for property owners, yet there are also benefits to water quality. Bioretention areas and grassed swales have been found to be effective at treating metals and nutrients in storm water runoff, as well as reducing runoff volumes (Montana Nonpoint Source Management Plan, 2007).

Sources of Funding: Clean Water Act, Section 319 - Nonpoint Source Grants

Section 319 of the Clean Water Act established the Nonpoint Source Management Program, which serves the need for greater local nonpoint source control strategies through allotment of grant monies. Such strategies and activities, which aim to ensure overall project success, include technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring. In applying for funds, facilitated by 319(h), it is important to note that monies are allocated according to each state's funding plan, which is submitted to the EPA and checked for consistency with the aims of the program (EPA, 2010).

Components

- Applications should include an identification and description of the best management practices and measures which the State proposes to assist, encourage, or require;
- The Federal share of the cost of each management program implemented with Federal assistance in any fiscal year shall not exceed 60% of the cost incurred by the State in implementing such management program and shall be made on condition that the non-Federal share is provided from non-Federal sources;
- No more than 15% of the amount appropriated to carry out the grant program may be used to make grants to any one State;
- Priority is given to programs addressing:
  - Control of particularly difficult or serious nonpoint source pollution problems (i.e. mining activities);
  - Implementation of innovative methods or practices for controlling nonpoint sources of pollution (includes regulatory programs);
  - Control of interstate nonpoint source pollution;
  - Implementation of ground water quality protection activities;
- The amount of any such funds not obligated, or spent, by the end of the fiscal year it was allotted shall be made available to the Administrator for granting to other States in the next fiscal year;
- Satisfactory progress and maintenance of efforts must be provided by each State;
- Reporting by each State, on an annual basis, shall be carried out for the progress of the programs (schedule of milestones) and shall provide reductions in nonpoint source pollutant loadings and improvements in water quality for those waters considered under the grant.

Purposes

- Demonstration of innovative best management practices (BMPs)
- Support of education and outreach programs
- Establishment of Total Maximum Daily Loads (TMDLs) for a watershed
- To restore impaired streams or other waters of the State

Base Projects v. Incremental Projects

Base projects are concerned with research-oriented, demonstrative, or educational purposes for identifying and preventing potential NPS areas in the state, where waters may be at risk of becoming impaired

Incremental projects are concerned with seeking to restore streams or other portions of watersheds that are already impaired and not presently satisfying their intended uses.

Other Funding Opportunities

- EPA Website concerning external funding opportunities: http://www.epa.gov/owow/nps/funding.html
- *Clean Water State Revolving Fund (CWSRF)*: low-interest loans (as low as 0% rates) for water quality protection projects, including wastewater treatment, NPS pollution control, and watershed and estuary management. http://www.epa.gov/owm/cwfinance/cwsrf/index.htm
- *Targeted Watershed Grants Program*: http://www.epa.gov/owow/watershed/initiative/
- *Environmental Quality Incentives Program:* http://www.nrcs.usda.gov/programs/eqip/
- *North American Wetlands Conservation Act Grants Program:* http://www.fws.gov/birdhabitat/index.shtm
- *Five Star Restoration Program:* http://www.epa.gov/owow/wetlands/restore/5star/
- *National Integrated Water Quality Program (NIWQP)*: http://www.csrees.usda.gov/fo/waterqualityicgp.cfm
- *Watershed Rehabilitation Program:* http://www.nrcs.usda.gov/programs/WSRehab/
- *The National Urban and Community Forestry Advisory Council (NUCFAC) - Urban and Community Forestry Challenge Cost-Share Grants:* http://www.fs.fed.us/ucf/nucfac
- *EPA Smart Growth Grants:* http://www.epa.gov/smartgrowth/grants/index.htm

References:

Arnold, C.L. and Gibbons, C.J., 1996, Impervious surface coverage: American Planning Association Journal, v. 62, no. 2, p. 243-258.

Hollis, G.E. 1975. The Effect of Urbanization on Floods of Difference Recurrence Interval. *Water Resources Research.* 11:431-435.

Prince George's County, Maryland Department of Environmental Resources, January 2000. *Low-Impact Development Design Strategies: An Integrated Design Approach*.

Roesner, L.A. and B.P. Bledsoe. 2003. *Physical Effects of Wet Weather Flows on Aquatic Habitats: Present Knowledge and Research Needs*. Water Environment Research Foundation. 00-WSM-4

Roesner, L.A., B.P. Bledsoe and R.W. Brashear. 2001. Are Best-Management-Practice Criteria Really Environmentally Friendly? *Journal of Water Resources Planning and Management.* 127:150-154.

United States Environmental Protection Agency (USEPA). 1997. Urbanization Streams: Studies of Hydrologic Impacts. 841-R-97-009.

U.S. Environmental Protection Agency, 2001, The Quality of Our Nation's Water, 1992, United States Environmental Protection Agency, EPA-841-S-94-002, Washington, D.C., USEPA, Office of Water.

Urbonas, B. and L.A. Roesner. 1992. "Hydrologic Design for Urban Drainage and Flood Control." In *Handbook of Hydrology*. Maidment, D.R. (Ed.), McGraw-Hill, Inc, New York, New York.

http://water.epa.gov/polwaste/nps/whatis.cfm, Date Accessed: 4 June, 2010. *EPA Nonpoint Source Pollution.*

http://www.taylorgeoservices.com/papers/point%20system.PDF, Date Accessed: 17 June, 2010.

http://www.lid-stormwater.net/background.htm, Date Accessed: 9 April, 2010. *Urban Design Tools: Low Impact Development.*

http://www.epa.gov/owow/nps/lid/, Date Accessed: 10 April, 2010. *EPA Low Impact Development (LID)*.

http://www.epa.gov/owow_keep/NPS/cwact.html, Date Accessed: 3 February, 2010. *Clean Water Act, Section 319*.

http://water.epa.gov/polwaste/nps/urban.cfm, Date Accessed: 28 December, 2010. *EPA*, *Urban Polluted Runoff*.

Chapter 2 - Background

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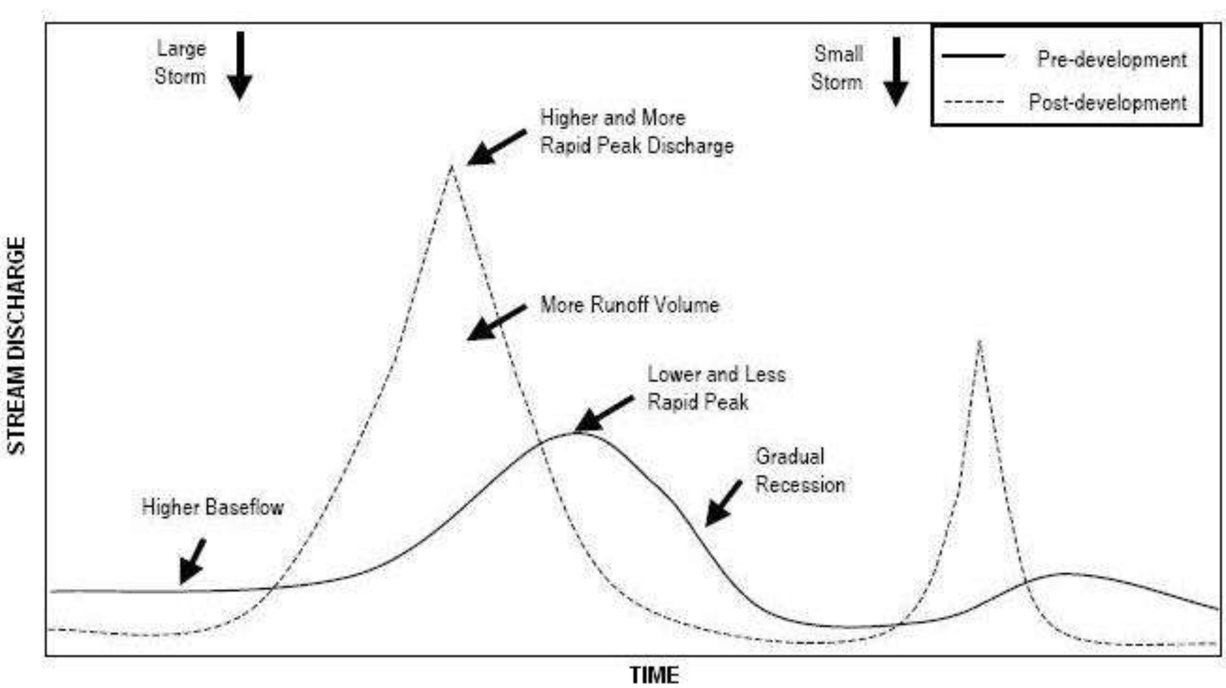

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Waste Disposal

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A properly maintained septic system can treat and, in some cases, completely remove contaminants from wastewater; however, several optimal conditions must first be met in order to avoid the release of excess pollutants to ground water and, ultimately, surface water. Associated with septic systems, common pollutants of concern include: nutrients (nitrogen and phosphorous), pathogens (bacteria, parasites, and viruses), household chemicals, personal care products (pharmaceuticals), and resultant byproducts (endocrine disrupting chemicals) (Montana Nonpoint Source Management Plan, 2007). Even under properly functioning conventional designs, septic systems are capable of releasing fairly high amounts of nitrogen, in the form of nitrate, which is "becoming a ubiquitous problem, particularly in rural and suburban areas where domestic water supplies are obtained from individual on-lot water supply wells" (Hagerty & Taylor). In the United States, septic system failure rates are estimated to range from 5 to 25 percent and higher (EPA, 2005). Accordingly, periodic maintenance and inspection are crucial for preventing septic system failure.

Roads

The state's transportation systems contribute greatly to NPS pollution, via storm water runoff, construction sites, maintenance activities, flood plain encroachment, and atmospheric deposition. Vehicles consistently release pollutants to the environment, such as oil and grease, particulate matter, and heavy metals (i.e. regular brake pad wear and tear), which can be picked up by storm water runoff and conveyed to receiving water bodies. In addition to runoff concerns, road construction may result in the constriction of flow at road crossings (including culverts and bridges), soil erosion, and head-cutting, all of which increase sediment loads and may also contribute to in-stream and riparian habitat modifications. Maintenance activities, such as roadside vegetation management and road sanding, can unintentionally contribute pesticides, sediment, and chlorides (via traction and deicing chemicals) to water bodies. Vehicle exhaust (nitrous oxides, particulates, lead, et cetera) contributes to air pollution and can affect water quality through atmospheric deposition (Montana Nonpoint Source Management Plan, 2007).

Best Management Practices (BMPs)

BMPs are applications that are designed to provide mitigation of pollution resulting from diffuse sources, such as those stemming from the urban and suburban sectors. BMPs are both technology- and education- based, with the goal of reducing contamination to the Maximum Extent Practicable (MEP). BMPs represent the operational activities, physical controls, or educational measures that are applied to reduce the discharge of pollutants and minimize potential impacts upon receiving waters. This approach includes both structural and non-structural practices, which have direct impacts on the release, transport, or discharge of pollutants (Field, 2004). A listing of such BMPs can be found in Appendix A.

In order to effectively diminish the adverse impacts associated with urban and suburban developments, integration and implementation of BMPs into the urban and watershed framework is necessary.

Low Impact Developments (LIDs)

Low impact development is an alternative, ecologically-sensitive design approach that imitates the processes that natural areas store and infiltrate rainwater. LID is a relatively new concept in the United States, first gaining momentum in Maryland in the 1990's (LID Center), but such practices are becoming the more sustainable and effective options to choose from. The LID approach protects local and regional water quality by decentralizing storm water conveyance and mitigating negative rainfall impacts throughout the urban landscape. LID consists of storm water management practices that can be incorporated within smart growth and/or green building strategies. However, LID techniques mainly focus on the hydrologic and ecologic impacts of site-specific development, with greater attention paid to quality control (Montana Nonpoint Source Management Plan, 2007). The objectives of LIDs are accomplished by:

- Minimization of storm water impacts to the MEP, via reduction of imperviousness, conversation of natural resources and ecosystems, maintenance of natural drainage courses, reduction in the use of pipes, and minimization of clearing and grading
- Providing storage of storm water runoff uniformly throughout the site's landscape, with a variety of detention, retention, and runoff practices, highlighting the enhancement of water quality aspects
- Maintaining or reestablishing predevelopment time of concentration by strategically routing flows, in order to maintain travel time and control the discharge
- Implementation of effective public education programs to encourage property owners to use pollution prevention measures and maintain the on-site hydrologically functional landscape management practices

Such actions are effective when uniformly spread or strategically integrated across the urban landscape (Prince George's County, 2000).

LID involves both structural and non-structural practices that aim to treat storm water as close to the source as possible. In doing so, this helps decrease the extent and cost of additional, downstream mitigation efforts. The basic idea of LIDs is to promote storage, infiltration, and ground water recharge, via storm water retention and detention areas, reduction and disconnection of impervious areas, and extending the flow paths and runoff (lag) times. Structural LID practices include bioretention facilities or rain gardens, grassed swales, soil amendments, vegetative roof covers or green roofs, permeable pavements, rain barrels and cisterns, and tree box filters. Non-structural LID practices include planning and management actions, such as the preservation of ecologically-sensitive areas (riparian corridors, mature trees, steep slopes, et cetera), disconnecting rain gutters from the storm sewer systems, and minimizing impervious surfaces (i.e. shared driveways).

LID practices require site-specific design and maintenance, but case studies exhibit an overall savings of 25 to 30 percent over conventional residential building techniques (LID Center). Cost savings and increased aesthetics provided by incorporating landscaping are incentives for property owners, yet there are also benefits to water quality. Bioretention areas and grassed swales have been found to be effective at treating metals and nutrients in storm water runoff, as well as reducing runoff volumes (Montana Nonpoint Source Management Plan, 2007).

Sources of Funding: Clean Water Act, Section 319 - Nonpoint Source Grants

Section 319 of the clean water Act established the Nonpoint Source Management Program, which serves the need for greater local nonpoint source control strategies through allotment of grant monies. Such strategies and activities, which aim to ensure overall project success, include technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring. In applying for funds, facilitated by 319(h), it is important to note that monies are allocated according to each state's funding plan, which is submitted to the EPA and checked for consistency with the aims of the program (EPA, 2010)

Components

- Applications should include an identification and description of the best management practices and measures which the State proposes to assist, encourage, or require;
- The Federal share of the cost of each management program implemented with Federal assistance in any fiscal year shall not exceed 60% of the cost incurred by the State in implementing such management program and shall be made on condition that the non-Federal share is provided from non-Federal sources;
- No more than 15% of the amount appropriated to carry out the grant program may be used to make grants to any one State;
- Priority is given to programs addressing:
    - Control of particularly difficult or serious nonpoint source pollution problems (i.e. mining activities);
    - Implementation of innovative methods or practices for controlling nonpoint sources of pollution (includes regulatory programs);

    - Control of interstate nonpoint source pollution;
    - Implementation of ground water quality protection activities;
- The amount of any such funds not obligated, or spent, by the end of the fiscal year it was allotted shall be made available to the Administrator for granting to other States in the next fiscal year;
- Satisfactory progress and maintenance of efforts must be provided by each State;
- Reporting by each State, on an annual basis, shall be carried out for the progress of the programs (schedule of milestones) and shall provide reductions in nonpoint source pollutant loadings and improvements in water quality for those waters considered under the grant.

Purposes

- Demonstration of innovative best management practices (BMPs)
- Support of education and outreach programs
- Establishment of Total Maximum Daily Loads (TMDLs) for a watershed
- To restore impaired streams or other waters of the State

Base Projects v. Incremental Projects

Base projects are concerned with research-oriented, demonstrative, or educational purposes for identifying and preventing potential NPS areas in the state, where waters may be at risk of becoming impaired.

Incremental projects are concerned with seeking to restore streams or other portions of watersheds that are already impaired and not presently satisfying their intended uses.

Other Funding Opportunities

- EPA Website concerning external funding opportunities: http://www.epa.gov/owow/nps/funding.html
- *Clean Water State Revolving Fund (CWSRF)*: low-interest loans (as low as 0% rates) for water quality protection projects, including wastewater treatment, NPS pollution control, and watershed and estuary management. http://www.epa.gov/owm/cwfinance/cwsrf/index.htm
- *Targeted Watershed Grants Program*: http://www.epa.gov/owow/watershed/initiative/
- *Environmental Quality Incentives Program:* http://www.nrcs.usda.gov/programs/eqip/
- *North American Wetlands Conservation Act Grants Program:* http://www.fws.gov/birdhabitat/index.shtm
- *Five Star Restoration Program:* http://www.epa.gov/owow/wetlands/restore/5star/
- *National Integrated Water Quality Program (NIWQP)*: http://www.csrees.usda.gov/fo/waterqualityicgp.cfm
- *Watershed Rehabilitation Program:* http://www.nrcs.usda.gov/programs/WSRehab/
- *The National Urban and Community Forestry Advisory Council (NUCFAC) - Urban and Community Forestry Challenge Cost-Share Grants:* http://www.fs.fed.us/ucf/nucfac
- *EPA Smart Growth Grants:* http://www.epa.gov/smartgrowth/grants/index.htm

References:

Arnold, C.L. and Gibbons, C.J., 1996, Impervious surface coverage: American Planning Association Journal, v. 62, no. 2, p. 243-258.

Hollis, G.E. 1975. The Effect of Urbanization on Floods of Difference Recurrence Interval. *Water Resources Research.* 11:431-435.

Prince George's County, Maryland Department of Environmental Resources, January 2000. *Low-Impact Development Design Strategies: An Integrated Design Approach*.

Roesner, L.A. and B.P. Bledsoe. 2003. *Physical Effects of Wet Weather Flows on Aquatic Habitats: Present Knowledge and Research Needs*. Water Environment Research Foundation. 00-WSM-4

Roesner, L.A., B.P. Bledsoe and R.W. Brashear. 2001. Are Best-Management-Practice Criteria Really Environmentally Friendly? *Journal of Water Resources Planning and Management.* 127:150-154.

United States Environmental Protection Agency (USEPA). 1997. Urbanization Streams: Studies of Hydrologic Impacts. 841-R-97-009.

U.S. Environmental Protection Agency, 2001, The Quality of Our Nation's Water, 1992, United States Environmental Protection Agency, EPA-841-S-94-002, Washington, D.C., USEPA, Office of Water.

Urbonas, B. and L.A. Roesner. 1992. "Hydrologic Design for Urban Drainage and Flood Control." In *Handbook of Hydrology*. Maidment, D.R. (Ed.), McGraw-Hill, Inc, New York, New York.

http://water.epa.gov/polwaste/nps/whatis.cfm, Date Accessed: 4 June, 2010. *EPA Nonpoint Source Pollution.*

http://www.taylorgeoservices.com/papers/point%20system.PDF, Date Accessed: 17 June, 2010.

http://www.lid-stormwater.net/background.htm, Date Accessed: 9 April, 2010. *Urban Design Tools: Low Impact Development.*

http://www.epa.gov/owow/nps/lid/, Date Accessed: 10 April, 2010. *EPA Low Impact Development (LID).*

http://www.epa.gov/owow_keep/NPS/cwact.html, Date Accessed: 3 February, 2010. *Clean Water Act, Section 319.*

http://water.epa.gov/polwaste/nps/urban.cfm, Date Accessed: 28 December, 2010. *EPA, Urban Polluted Runoff.*

Chapter 3: Utah's Nonpoint Source Pollution Control Strategy

This section of the Stormwater Management Plan of the Utah Nonpoint Source (NPS) Plan describes the program goals and objectives, in addition to defining the state's array of control strategies. These include: water resource-specific and land use-specific actions, public education and outreach (E&O), interagency coordination, and enforceable regulatory components. In addition, the control strategies will be elaborated upon, via specific actions.

Utah's strategy for addressing NPS pollution includes protection of currently unimpaired water sources through the use of appropriate best management practices (BMPs), preference and recommendation for implementing innovative measures (such as low impact development practices (LID)), and statewide E&O activities. For waters not currently attaining standards, Utah's strategy is to restore these waters through the development and implementation of science- and research-based, locally-supported watershed restoration plans.

For impaired waters, delineated with the help of the Clean Water Act's Section 303(d) Total Maximum Daily Load (TMDL) program, NPS load allocations should be met through the use of reasonable land, soil, and water conservation practices, as identified in the Water Quality Plans and Watershed Restoration Plans.

BMPs have traditionally focused on managing the stormwater runoff associated with either a given design storm or a flood scenario, both of which provide large quantity control (i.e. flooding) while neglecting to enhance quality. As a result, the state of Utah has employed numerous systems, primarily aimed at detention, which do little to improve quality and tend to exacerbate, rather than mitigate, erosion potentials in the receiving environments downstream of such BMPs. Thus, it is imperative to initiate the move from a water quantity only focus to that of a more holistic, water quality and quantity focus. The following design and stormwater quality principles, as set forth by the City and County of Denver's *Water Quality Management Plan* (2004), can be applied in order to attain the desired response:

Principle 1: Consider stormwater quality needs early in the development process

As opposed to the traditional method of applying BMPs to fit a site's constrained needs, future direction should unite the processes in order to achieve the most efficient use of a site's characteristics and resources, such as stormwater runoff. Both site and stormwater control designs are fundamental and, thus, should be integrated early in the project's life.

Principle 2: Take advantage of the entire site when planning for stormwater quality treatment

Through integration of preliminary steps, the ability to maximize the BMP as a part of the overall site design will facilitate both management of site-generated runoff and downstream BMP costs.

Principle 3: Reduce runoff rates and volumes to more closely match natural conditions

Since urbanization is linked to increased impervious surfaces and, therefore, increased runoff rates and volumes, it is important to set the aim of meeting predevelopment hydrologic conditions to the maximum extent practicable. This can be achieved on an urban site by: (a) disconnecting directly connected impervious areas (application of MDCIA principle) and reconnecting stormwater with the site soil and vegetation (via grass buffers, swales, etc); (b) reducing the total amount of a site's impervious area (via porous pavements, green roofs, etc); and, (c) selecting treatment areas that promote greater infiltration (via porous landscape detention, porous pavement, and sand-filter detention). Such practices can halt the urbanized increase in runoff and prevent the downstream erosive and pollution capabilities.

Principle 4: Integrate stormwater quality management and flood control

The majority of annual precipitation events within Utah produce stormwater runoff depths of less than 0.1 inch. The remaining events amount to less than 0.6 inches (finalize data with these numbers). On the other hand, the majority of Utah stormwater BMPs are aimed at mitigating these less frequent, larger storm events, thereby neglecting quality improvement aspects of BMP design.

Several water quality systems, such as extended detention basins, retention ponds, wetland basins, and sand filter basins can be modified to address flood control in addition to the water quality capture volume. Additionally, applying the treatment train approach to stormwater BMPs can provide a multi-purposed, holistic method in urban and suburban areas.

Principle 5: Develop stormwater quality facilities that enhance the site, the community, and the environment

The use of vegetation in BMP design often lends itself to several secondary benefits, in addition to quality improvement, such as green space enhancement, wildlife habitat, multiple recreational uses, and higher property values. Such facilities also allow for integration of community and local themes, greatly enhancing the aesthetics of an otherwise utilitarian structure.

Principle 6: Design sustainable facilities that can be safely maintained

Holistic design systems typically involve regular maintenance and, therefore, must provide safe and reliable avenues for such, including: mowing, trimming, and weed control; pruning of shrubs and tree limbs; cleanup of collected trash and debris, especially at grates and flow control structures; sediment removal; removal, replacement, and revegetation of porous landscape detention media, such as mulch; and, vacuuming/replacing porous pavement areas. This can be accomplished by, first, establishing stakeholders early in the design process and, second, synthesizing a plan for continued inspection and maintenance of the BMPs.

Principle 7: Design and maintain facilities with public safety in mind

Of highest importance to engineers, public officials, and responsible citizens are the protection of public health, safety, and well-being. Therefore, stormwater quality BMPs must be designed, inspected, and maintained to the highest degree possible such that health and safety hazards are nonexistent. The following BMP characteristics and practices can be employed in order to reduce hazards: pond edges created with gradually sloping banks within 10 to 20 feet of shoreline; reduction of perimeter wall heights to the maximum extent practicable; inclusion of railings on vertical drops of 30 inches or more (check with municipal building codes); siting facilities with steep sides away from major pedestrian routes; providing an emergency egress route; and improving visibility to the maximum extent practicable, by avoiding walled-in or steeply sloped remote ponds, and providing for site lighting.

See Volume 3 of the Urban Drainage and Flood Control District's (UDFCD's) *Urban Storm Drainage Criteria Manual* (1999, 2001) concerning the proper methods for selecting and implementing urban stormwater BMPs with regard to quality control.

Goals and Objectives

The goal of Utah's Nonpoint Source Management Program is to protect and restore water quality from the impacts of nonpoint sources of pollution in order to provide a clean and healthy environment. The short-term (five-year) goal of Utah's Nonpoint Source Management Program is to demonstrate significant progress in protecting and restoring the water quality of Utah from nonpoint sources of pollution as measured by achieving the actions outlined in this plan. In order to accomplish the goals of the NPS Program, Utah DEQ will employ the following principles

- Support local conservation activities
- Continue comprehensive assessments through the TMDL development process
- Improve collaboration with other programs, agencies, and organizations
- Enhance the connection between planning and implementation
- Utilize adaptive management to achieve the goal of the program

In order to meet the demands of mitigating nonpoint source pollution originating from both urban and suburban sources, the state has established an action plan. This plan maintains five (5) objectives, pertaining to the ultimate goal of protecting the state's waters from further degradation due to impaired stormwater runoff. These objectives are established in the tables that follow (Tables 1 through 5).

Diffuse Urban and Suburban Pollution Control Measures

Diffuse urban and suburban NPS pollution may be addressed through public education and involvement, enforcement of illicit discharge regulations, and effective management by state and local entities over NPS water quality resulting from industrial activity, construction sites, and new and existing developments and infrastructure.

Phase I and Phase II NPDES Permits address point sources, such as industrial, construction, mining and extraction, and municipal separate storm sewer systems (MS4s). These sources of pollution are not considered under the NPS plan since the discharges are regulated by the permit system.

Improved planning for urban and suburban growth and development is essential for the management of storm water runoff and protection of water quality in higher population density areas. Planning to protect sensitive areas, such as wetlands and riparian corridors, and incorporating technologies that infiltrate storm water runoff and filter pollutants will assist in the preservation of water quality. Improvements in water quality may also result when 'retrofit' designs or practices are applied to existing structures. An example of a retrofit design that directly benefits water quality is that of replacing concrete medians with vegetated swales, while an example of a retrofit practice includes institution of a recycling program not already in practice.

Land use planning that incorporates 'smart growth' principles has the potential to assist in preventing NPS pollution from urban and suburban sources. Smart growth is not a rigid design, but rather a template of sustainability principles that can be employed during the land use planning process. The idea of sustainable land use practices promoted by smart growth applies to the protection of water quality. The federal government, through the efforts of the U.S. EPA, promotes the use of smart growth principles for environmental protection, since "development guided by smart growth principles can minimize air and water pollution."[1]

Control measures are the actions required, outlined within the NPS Stormwater Management Plan, that serve to meet the goal of a reduction of nonpoint source pollution, resulting from urban and suburban sources, through both public and private enterprises. Objectives and corresponding actions are summarized in Table 3.1.

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[1] http://www.epa.gov/smartgrowth/index.htm), Date Accessed: 6/24/2010

Table 3.1 Summary of Objectives and Actions.

Objective #1: Implementation of management practices across the entire watershed, focusing on urban and suburban source of nonpoint source pollution	
Actions:	
1a	Assist and support the local land use planning process with improved stormwater BMP design such that negative water quality impediments resulting from developed areas are considered on a watershed basis.
1b	Provide the means and basic information on methods that maximize a site's recharge and infiltration capabilities, minimize the presence and effects of impervious cover (via disconnecting impervious areas, use of pervious areas for filtering stormwater, and replacing curb-and-gutter systems with swales), conserving existing green cover (forested and other vegetated areas), and revegetating green areas (i.e. turf).
1c	Provide information on stormwater BMPs focusing on stormwater mitigation for all designs and applications within the urban and suburban area (i.e. natural buffers, bioswales, alternative pavement options, maintaining soil quality, green roofs, rain gardens, native landscaping, xeriscaping, etc.).
1d	Promote the voluntary application of stormwater BMPs to prevent and minimize urban and suburban developments' effects on stormwater runoff. Focus on sustainability and successful long-term maintenance.
1e	Encourage expansion of watershed councils and committees members to include representatives from municipalities, local businesses, construction corporations, developers, and realtors.
1f	Coordinate the statewide efforts of the NPS Plan with those of the 303(d) TMDL system, in order to provide a watershed-wide solution to stormwater management and accounting for future growth allocations.
1g	Provide city and county commissioners with information regarding the ties between water quality and land use planning, with examples of successful BMPs used to manage stormwater in addition to the potential benefits and difficulties associated with each.
1h	Conduct and promote campaign and marketing advertisements, highlighting new, innovative, and creative ideas to reduce urban and suburban impacts to water quality.
1i	Encourage incentive-based planning with local businesses and residential areas that includes solutions to water quality impacts from development.

1j	Support development and continuation of local information and education campaigns aimed at reducing pollutant runoff from all sources (construction, transportation, businesses, developers, and homeowners).
1k	Promote city- and county-wide recycling and hazardous waste collections systems.
Objective 2: Reduction of nutrient-rich runoff from entering surface and ground water sources resulting from urban and suburban land uses, such as septic systems and other nonpoint source activities, via education and outreach (E&O) means.	
***Actions*:**	
2a	Provide education materials for policy makers, planners, and landowners regarding the impacts of septic systems (on-site wastewater systems) on ground and surface waters and how to address elevated levels of nutrients through alternatives; emphasis on sustainable systems.
2b	Work with CDs and watershed groups to develop local outreach efforts to reduce nutrient impacts associated with urban and suburban land use activities (i.e. lawn and fertilizer applications, confined animal operations, construction sites, and pet wastes).
2c	Promote voluntary nutrient reduction programs in rapidly developing and projected areas of the state in addition to sites of concern, where elevated nutrient loading to state waters is s concern.
2d	Provide information on the benefits of small-scale, centralized distribution and treatment systems of water and wastewater within new developments, encouraging community wells and wastewater treatment systems. Additionally, provide information regarding decentralized, sustainable systems. Focus on city and county commissioners and DEQ Permitting Division employees.
2e	Promote natural or engineered systems, such as constructed wetlands, riparian corridors, and vegetated filter strips for treatment of urban nonpoint source pollution (i.e. stormwater runoff, effluent treatment).
Objective 3: Reduction of nonpoint pollution source impacts associated with urban/suburban transportation systems	
***Actions*:**	
3a	Review state and federal highway projects possessing the potential to affect water quality and provide recommendations based on reducing nonpoint source pollution impacts.

3b	Reduce the generation of pollutants from road maintenance operations by minimizing use of salts, sands, pesticides, herbicides, and fertilizers.
3c	Develop a training program for state and county road maintenance crews to maximize road maintenance activities and reduce sediment/pollutant loading to associated water bodies.
Objective 4: Encourage cities and counties to develop zoning ordinances and/or regulations that promote water body buffer zones and setbacks, focus on water quality.	
Actions:	
4a	Develop a task force aimed at protecting riparian areas through the promotion of riparian buffers and stream corridor protection initiatives.
4b	Provide education materials for policy makers, planners, and landowners regarding the benefits of buffers and setbacks.
4c	Make buffers/setback guidance available and easy to apply for city and county planners and landowners.
Objective 5: Protect wetlands from adverse stormwater impacts.	
Actions:	
5a	Provide information to local governments on stormwater criteria to provide wetland protection when working in or near wetlands, working in the contributing drainage area, and how to manage developed areas established within the contributing area.
5b	Provide information to developers to discourage the use of natural wetlands as storm water treatment mechanisms, particularly for receiving the discharge of untreated stormwater. Avoid locating stormwater treatment practices in wetland buffer zones and riparian corridors.
5c	Provide information to developers to discourage the use of designs that constrict wetland outlets.
5d	Create education and outreach materials explaining the differences between natural and constructed/engineered treatment wetlands, including how to construct and who to contact when developing effective treatment wetlands.

Chapter 4: Measuring Success

Description

The purposes of this management measure serve to determine the following:

- Whether implementation of the runoff management program framework is protecting and/or improving water quality by evaluating management practices that are in use to meet the program framework and objectives, as outlined in Chapter 3. If these practices fall short of effective, then improvements to the runoff management program framework should be instituted.
- Periodic reassessment of the watershed to determine whether water quality has improved or declined. As a result of this assessment, each management measure should be reevaluated to determine whether or not additional practices are necessary, if improvements should be made to existing programs, or if specific practices are obsolete and should be halted.

This chapter is important since runoff management programs should not be static and, therefore, should periodically reassess programs in order to increase effectiveness and efficiency. Areas where improvements are necessary should be identified, via review and reassessment, and augmented to better suit the program goals. Additionally, such improvements carry with them increased overall optimization, with a greater chance for public and political backing. The basic elements of a successful program evaluation are described within this chapter detailing management measures.

Management Practices

Assess the Runoff Management Program Framework

Assessment should be undertaken periodically in order to determine aspects of the program's goals and objectives that require strengthening or revision, with each aspect of the framework requiring a different type of measurement (qualitative v. quantitative v. quality assurance/quality control).

Track Management Practice Implementation

Implementation monitoring can be used to determine the extent to which management measures and practices are implemented in accordance with relevant standards and specifications. This involves establishing a program that tracks either whether the practices have been implemented or whether management practices have been operating and maintained as designed. This can be carried out via several methods, including: permit tracking, operation and maintenance records, geographic information systems, development of surveys, and consideration of expert evaluations.

Gauge Improvements in Water Quality Resulting from Management Practice Implementation

The most important step in the development of a monitoring plan is to define the goals of the program and maintain them throughout the assessment. Monitoring goals are broad statements that include an umbrella aim, allowing for loose interpretations. However, in addition, designing monitoring plans also includes selecting sampling variables, a sampling strategy, station locations, data analysis techniques, the length of the monitoring program, and the overall level of effort to be invested.

Once the monitoring goals have been established, existing data and constraints should be considered. A thorough review of literature pertaining to water quality studies previously conducted in similar geographic regions should be completed beforehand. This review should aid in determining whether existing data provides sufficient information to address the monitoring goals and whether data gaps exist.

The next step should be to identify project constraints such as finances, staffing, and time. Clear and detailed information should be obtained on the time frame for management decisions, the amounts and types of data that must be collected, the level of effort required to collect them, and the equipment and personnel needed to conduct the monitoring. This will determine whether available personnel and budget are sufficient to implement or expand the monitoring program.

As with its design, the program's level of monitoring is largely determined by the goals and objectives that are established, although some flexibility exists for achieving most monitoring objectives. It is also important to ensure that the expectations for the monitoring program are realistic. The following key steps, by Ward et al. (1990), for ensuring what types of information a monitoring program can produce include:

- Perform a thorough review of the legal basis for the management effort and define the resulting implications for monitoring,
- Review the administrative structure and procedures developed from the law in order to define the information expectations of the management staff,
- Review the ability of the monitoring program to supply information,
- Formulate an information expectations report for the monitoring system,
- Present the information expectations report to all users of the information, and
- Develop consensus as to an agreeable formulation of information expectations and related monitoring system design criteria.

Appendix A

Urban and Surburban Stormwater Best Management Practices

Capture Retain Detain

- Bioretention…… A-1
- Constructed Wetlands…… A-8
- Detention Systems…… A-14
- Dry Swales…… A-18
- Infiltration Basins…… A-22
- Infiltration Trench…… A-28
- On-Site Infiltration…… A-33
- Rainwater Harvesting…… A-37
- Retention Systems…… A-40
- Soil Erosion Control…… A-45

Filters Flow Control Seperators

- Check Dams…… A-49
- Dikes, Berms, Swales…… A-52
- Oil Grit Seperators…… A-55
- Permeable Weirs…… A-60
- Proprietary Flow Control Devices…… A-63
- Surface Sand Filters…… A-65
- Underground Filters…… A-70

Impervious Surface Reduction

- Cul-de-Sac Design…… A-74
- Green Rooftops…… A-77
- Minimization of Land Clearing and Disturbance…… A-80
- Parking Lot Design…… A-83
- Street Design…… A-85
- Turf, Porous Pavers, Permeable Pavement…… A-89

Management

- Animal Management…… A-94
- BMP Maintenance…… A-96
- Pavement Management…… A-101

Vegetation Measures

- Aquatic Buffers…… A-104
- Filter Strips…… A-109
- Landscape Design and Maintenance…… A-114
- Soil Erosion Control Management…… A-117
- Vegetative Stabilization…… A-120

Bioretention

Potential Applications

This BMP combines the mitigation properties of microbial activity (for quality issues) with physical treatment, such as adsorption and filtration. Bioretention is typically applied at small sites and in ultra urban areas (U.S. EPA, 2006). It is also used at stormwater hot spots, as a stormwater retrofit, and near cold water streams (Barr Engineering Co., 2001). However, as size is the limiting factor, proper attention should be given when siting, designing, and constructing bioretention units in all scenarios.

Brief Description

These BMPs are typically designed as shallow, vegetated catchment areas that receive stormwater runoff resulting from nearby impervious surfaces (such as parking lots). The stormwater enters the unit, is allowed to pond at the surface, and gradually infiltrates into the soil/substrate layer. The focus of such units is on small storm hydrology with larger storms being allowed to flow through or be diverted directly to the storm drain system.

Pollutant removal occurs through several processes, including: adsorption, filtration, volatilization, ion exchange, and decomposition (Prince George's County, MD, 1993). The filtered runoff can then either be allowed to percolate into the surrounding, in-situ soil or be collected and discharged to the storm sewer system via an underdrain. Refer to Figure 1 for visuals of a typical bioretention unit.

Considerations

Prior to construction, drainage area should be determined, with a maximum size of two acres, since larger areas result in increased clogging, decreased

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction (infiltration systems only)	◧
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	■
Nitrogen (N)	■
Heavy metals	■
Floatables	◧
Oil and grease	■
Fecal coliform	◧
Biochemical Oxygen Demand (BOD)	◧

ability to manage and convey runoff flows, and greatly increased costs of the unit. Similarly, bioretention units function best when slopes are relatively shallow. Additionally, environmental and climate conditions should be considered, since high groundwater tables, cold weather climates, and in-situ soils with low permeability can disrupt and damage bioretention units.

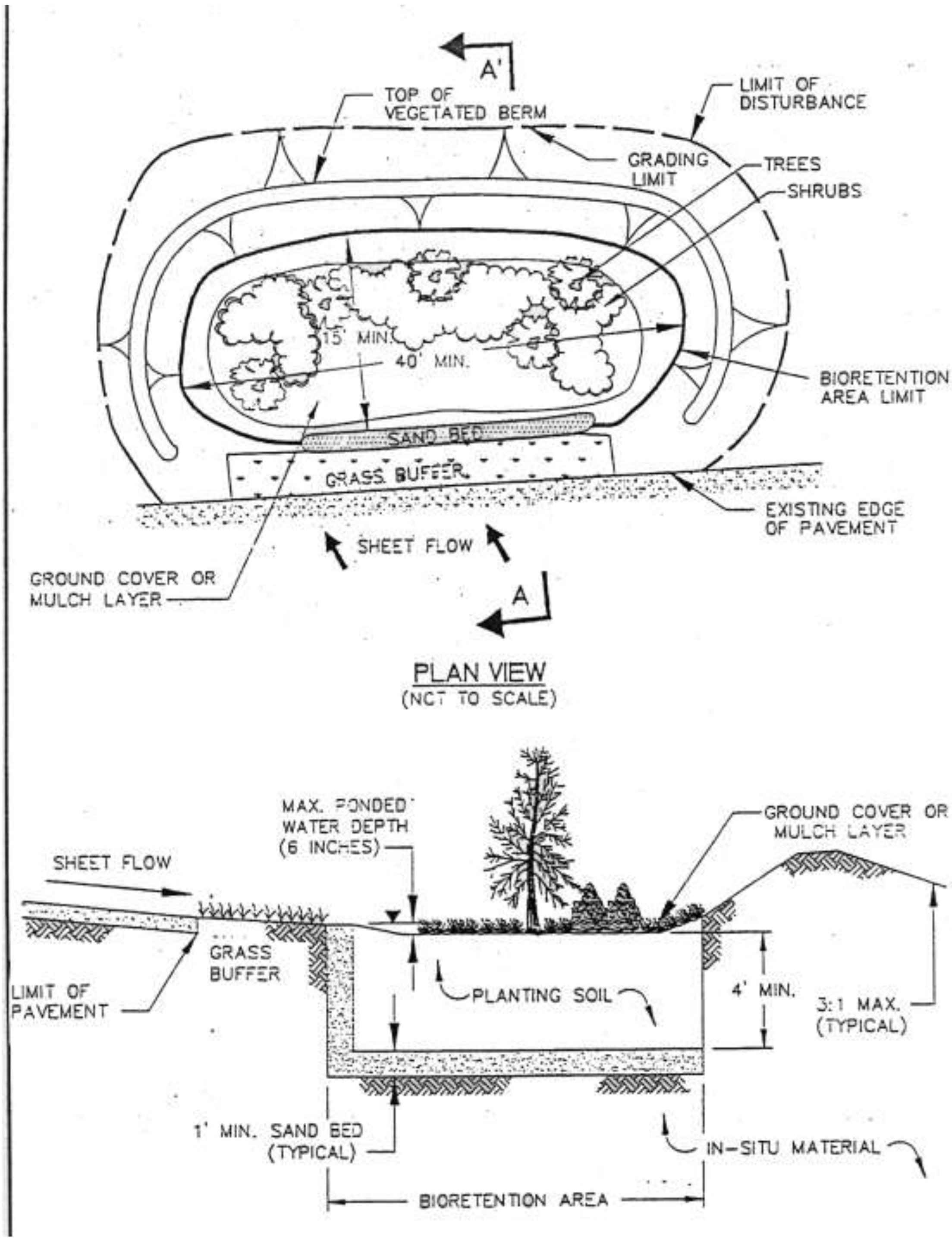


Figure 3: Typical Bioretention Plan and Profile Views (Cited by Barr Engineering Co., 2003; Source: Prince George's County, 1993)

Design Guidelines

Bioretention units typically include the follow components: a pretreatment area, a ponding area, an organic mulch layer, a planting soil bed, an underdrain system, an overflow structure, and vegetation. Pretreatment is essential in removing as much suspended sediment and floatable materials prior to runoff reaching the main system. Properly designed and maintained pretreatment systems allow for increased functionality and longevity of the bioretention unit. The ponding area of the BMP allows for surface storage of stormwater runoff, prior to infiltration.

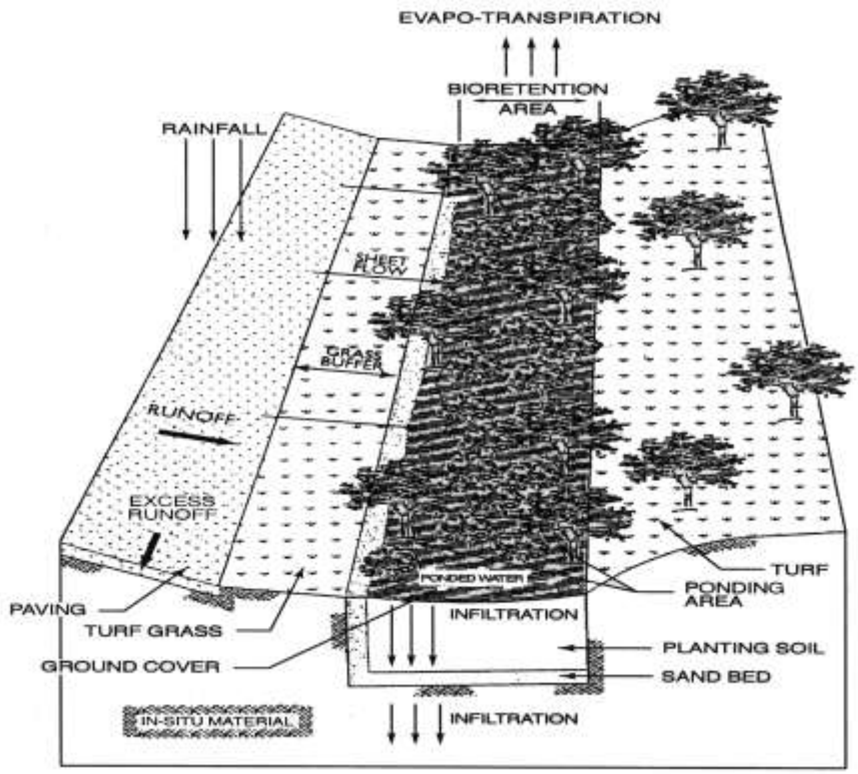


Figure 4: Bioretention Unit Conceptual Layout, Serving as an Infiltration Basin (Cited by U.S. EPA, 1999; Source: Prince George's County, 1993)

The organic mulch layer allows for prevention of soil bed erosion, moisture retention in the plant root zone, a medium for biological growth and decomposition of organic matter, and some filtration of pollutants. The planting soil bed layer provides the growth media for the vegetation and accompanying roots and allows for filtration, adsorption, and biological degradation of pollutants. The underdrain system, whose presence is dependent upon site characteristics and goals, serves to collect and convey infiltrated runoff from the base of the unit. The overflow structure aids in conveying flows that exceed the BMPs capacity to either a nearby water body or storm drain system. Last, the vegetation provides removal and treatment of contaminated water, via evapotranspiration and biological activity. For a list of vegetation specific to the state of Utah, refer to the Utah Native Vegetation List in Appendix B. Refer to Figure 2 for a conceptual layout of a bioretention unit, serving as an infiltration basin, and Figure 3 for a bioretention area as a parking edge and perimeter without curb.

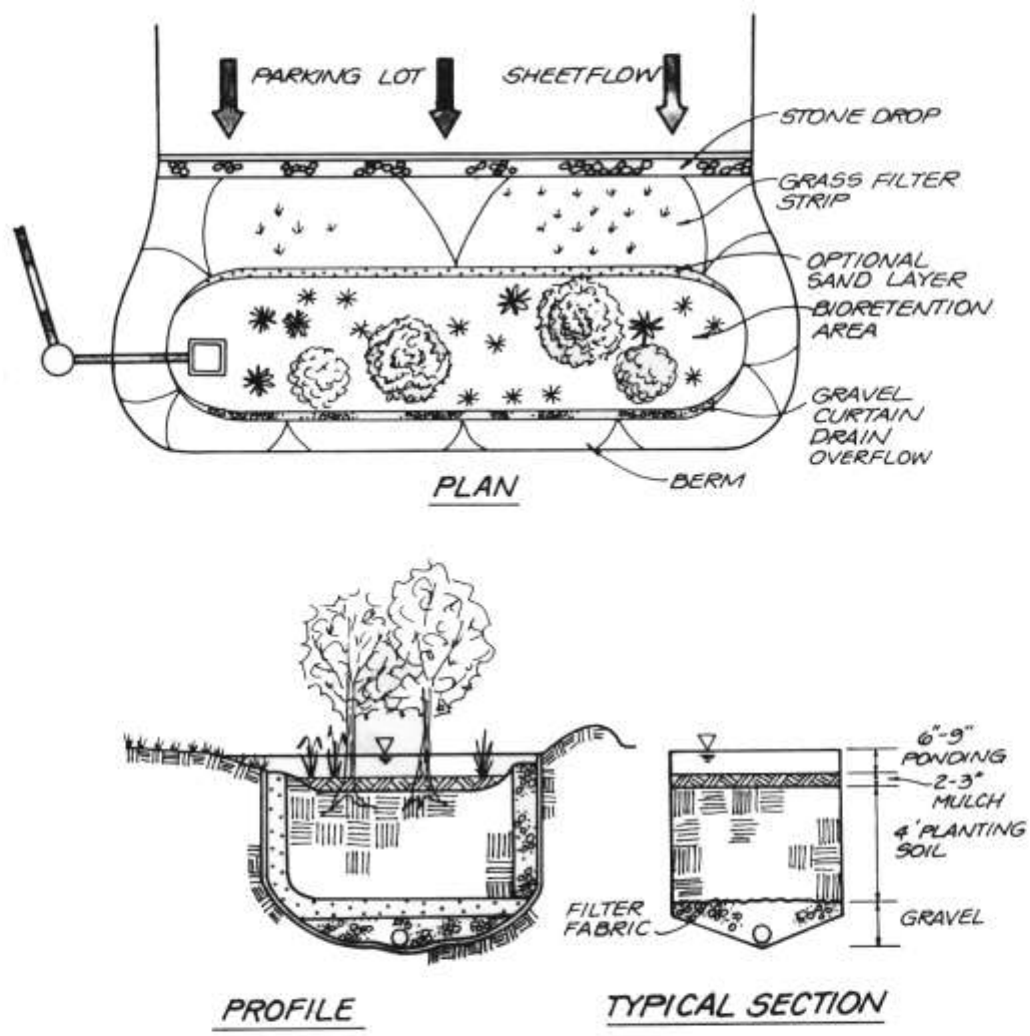


Figure 5: Plan and Profile Views of a Bioretention Unit as a Surface Sand Filter (Cited by Barr Engineering Co., 2003; Source: Center for Watershed Protection, 1996)

Maintenance Recommendations

The following schedule of maintenance activities is recommended and approved by numerous organizations, include the Stormwater Manager's Resource Center (SMRC, n.d.) and the Metropolitan Council (Barr Engineering Co., 2001). The activities are differentiated by the degree to which they must be carried out.

Regular/Frequent

- Irrigation of vegetation throughout the vegetation establishment period and first growing season, to ensure survival;

- Removal of litter and debris.

Regular/Infrequent

- Removal of sediments and revegetation in areas of buildup;
- Limit fertilizer application, based on plant vigor and soil test results;
- Treatment of diseased shrubs and trees.

Annual (Semiannual in the first year)

- Inspection of soil and repair eroded areas;
- Replenish void areas with additional mulch.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Bioretention Systems*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STFiltBioretention.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 9.1: Bio-retention Basin/Rain Garden (RaG).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/9.1rag.pdf.

Claytor, R. and Schueler, T. (1996). *Design of Stormwater Filtering Systems*. Prepared for the Center for Watershed Protection. Retrieved October 25, 2011, from http://pittsburghpermaculture.org/wp-content/uploads/2010/04/stormwater_filtration_system_design.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Bioretention*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm.

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Bioretention*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_biortn.pdf.

U.S. EPA (2006, May). *Bioretention (Rain Gardens)*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=72&minmeasure=5.

Constructed Wetlands

Potential Applications

Constructed wetlands are built as either stormwater wetlands or wet swales, with the sole purposes of (1) maximizing pollutant removal from stormwater runoff and (2) to provide flood control for large drainage areas. This BMP is typically applied as a series configuration, which combines structural and/or non-structural stormwater runoff treatment mechanisms rather than a single method. This system of BMP application is also known as a treatment train.

Brief Description

Constructed wetlands are engineered systems that mimic and enhance the natural processes of a healthy wetland ecosystem. Such systems consider the present conditions and anticipated outcomes in order to provide a design that is effective at enhancing both water and environmental quality. These systems utilize the natural processes of wetland vegetation, soils, and associated microbial parameters to assist in the treatment of applied water sources. Figure 1 presents a generalized constructed wetlands design, involving several processes for water quality and water quantity mitigation.

Considerations

Since such systems are complex, involving both structural and non-structural components, professionals should be consulted throughout the design, construction, and management stages. Constructed wetlands provide for water quantity treatment through attenuation, or slowing down, of runoff flows. Water quality is addressed by increasing the settling ability of turbid (high suspended sediment load) waters, removal of organics and heavy metals through natural processes (i.e. vegetation uptake), and

Purposes

	Water Quantity
Flow attenuation	■
Runoff volume reduction	◧

	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy metals	◧
Floatables	◧
Oil and grease	■
Fecal coliform	■
Biochemical Oxygen Demand (BOD)	■

treatment of other pollutants, such as pathogens and biochemical oxygen demand (BOD) (Barr Engineering Co., 2001).

When considering a constructed wetland system as a BMP, the following must be taken into account:

- Site topography;
- Soils;
- Length to width ratios;
- Unit configuration;
- Number of treatment cells;
- Open water to vegetation ratios;
- Inlet and outlet structures, with pretreatment;
- Internal structural components (i.e. baffles, pipes, and recirculation).

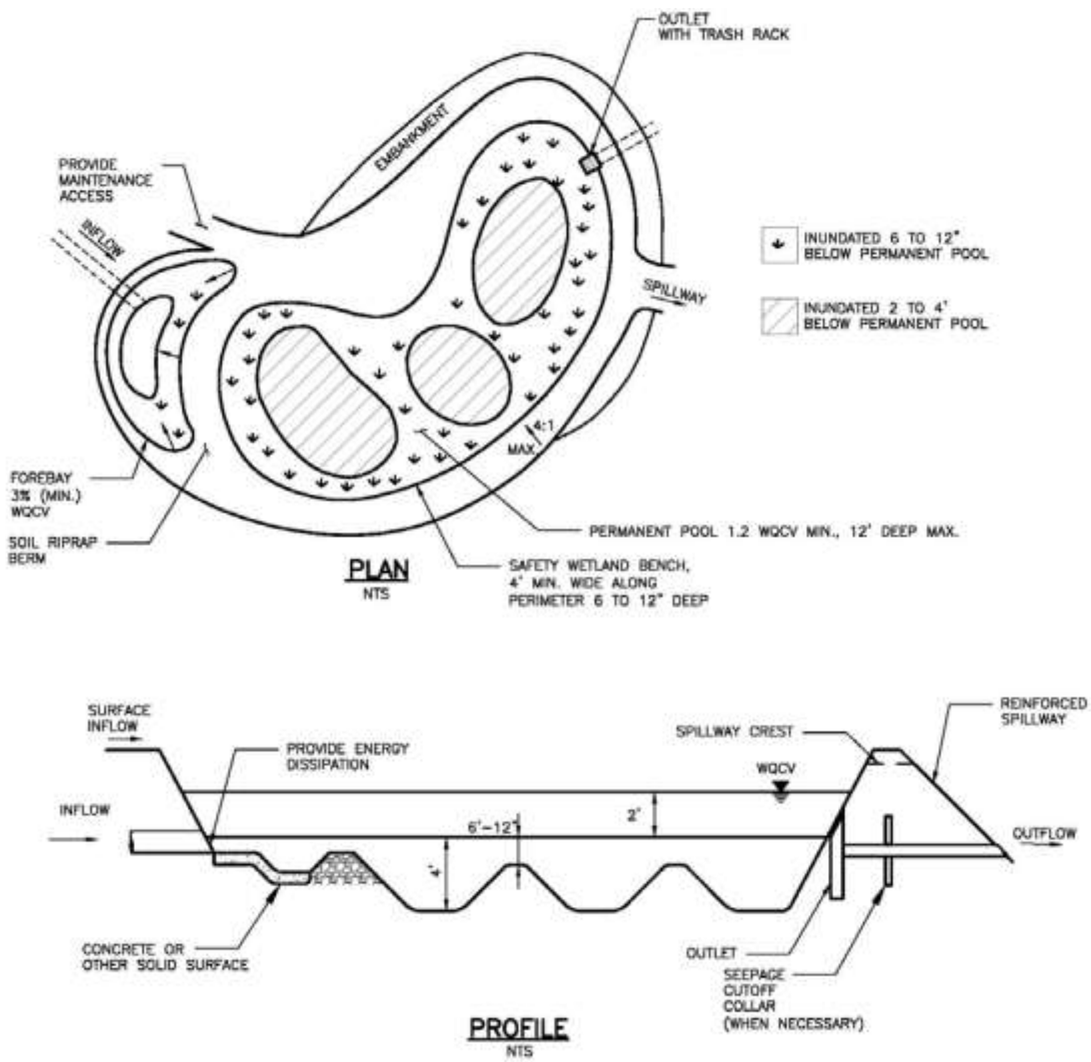


Figure 6: Plan and Profile View of a Constructed Wetland (Source: UDFCD, 2010)

Design Guidelines

Since such BMPs should be planned and designed by professionals, only generalized design guidelines are presented for the FWS (see Figure 2) and VSB (see Figure 3) wetland systems.

FSW System

First, loading rates, or runoff volumes, must be determined for the unit. This parameter helps identify the required areal footprint of the system. Second, sizing for settling of total suspended solids is carried out, accounting for both ponding and vegetation. Within the wetland, there must be areas, known as cells, which allow for a range of environmental condition. These cells provide for oxygenated (aerobic) and non-oxygenated (anaerobic) zones, which facilitate the numerous biological, physical, and chemical treatment processes. Last, based on water quantity control goals, the inlet and outlet structures must be designed to properly manage the supplied runoff (NRMRL, 2000).

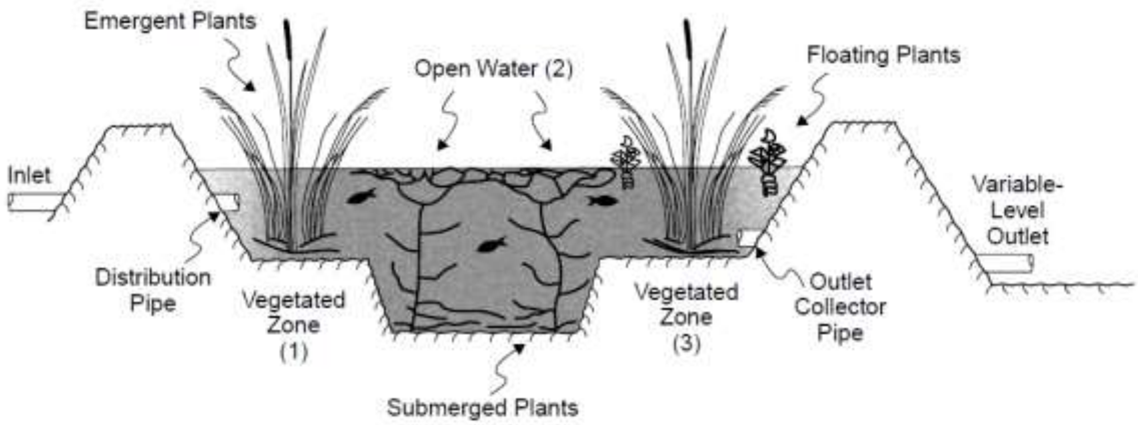


Figure 7: Free Water Surface Constructed Wetlands Schematic (Source: U.S. EPA, 2000)

VSB System

As for the FSW system, the initial step is determination of the loading rates; however, water quality goals are met by altering the subsurface storage conditions. This type of constructed wetland is similar in design and functionality to a bioretention unit. All treatment processes are carried out underground, in the void (i.e. empty) spaces of the porous media. Atop the substrate layer is a diversity of wetlands vegetation. In providing for appropriate space and maintaining vegetative health, the physical, biological, and chemical processes are properly carried out (NRMRL, 2000).

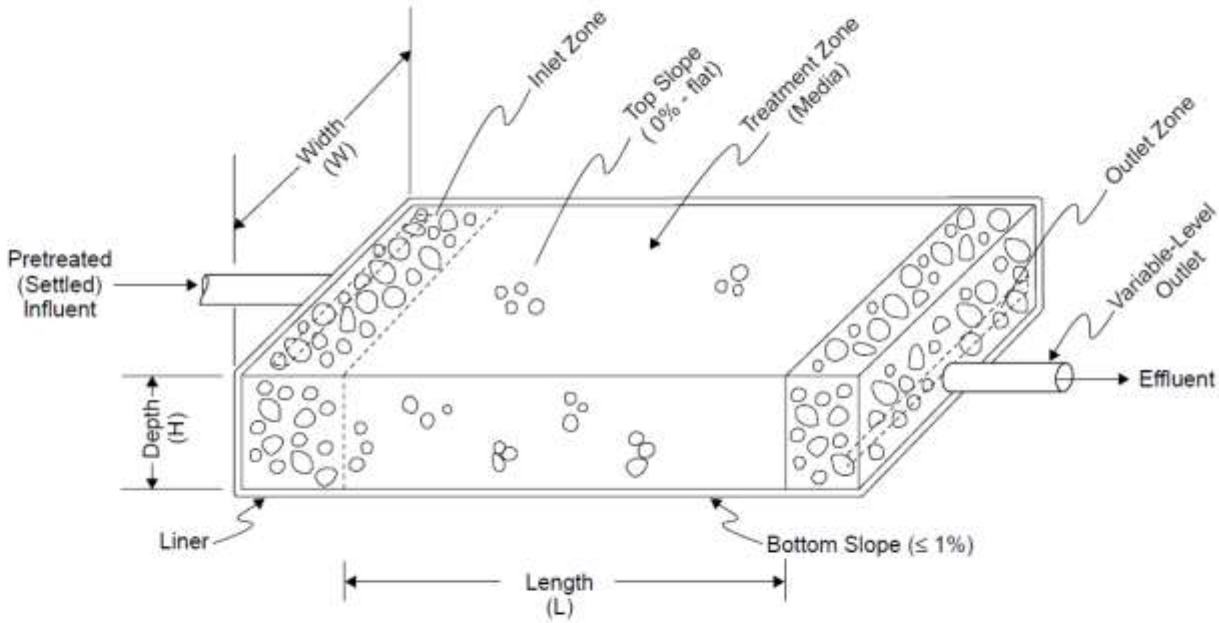


Figure 8: Vegetated Submerged Bed Constructed Wetlands Schematic (Source: U.S. EPA, 2000)

Maintenance Recommendations

Constructed wetlands are considered natural systems, therefore operation and maintenance approaches are typically regarded as hands-off. However, the following aspects of the unit should be considered (SMRC, n.d.):

- Changes in water surface levels (if a FWS system) or significant pooling of water on the soil surface (if a VSB system);
- Maintenance of flow uniformity for both the inlet and outlet structures;
- Vegetative health;
- Control of odors;
- Control and/or elimination of vectors (i.e. pests and insects);
- Maintenance of berms and dikes.

Establishment of a monitoring program can be helpful in managing a constructed wetland system. In general, monitoring of water quality indicators, water levels, and biologic indicators should be conducted regularly, in order to assure proper functioning of the system. Over time, these data parameters can help operators predict potential problem areas and aid in the selection of the appropriative remedial measures (Barr Engineering Co., 2001).

References

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Stormwater Wetlands*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/water/bmp/CH3_STConstWLSwWetland.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 9.4: Constructed Wetlands (CW).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/9.4cw.pdf.

Davis, Luise (n.d.) *A Handbook of Constructed Wetlands: a guide to creating wetlands for Agricultural Wastewater, Domestic Wastewater, Coal Mine Drainage, Stormwater in the Mid-Atlantic Region, Volume 1 – General Considerations.* Prepared for the USDA-Natural Resources Conservation Service and the U.S. EPA. Retrieved June 2, 2011, from http://water.epa.gov/type/wetlands/restore/upload/1998_04_02_wetlands_pdf_hand.pdf.

Federal Remediation Technologies Roundtable, FRTR (n.d.). *3.11 Ex Situ Biological Treatment (assuming pumping) - 4.42 Constructed Wetlands.* Retrieved June 3, 2011, from http://www.frtr.gov/matrix2/section4/4-43.html.

Interagency Workgroup on Constructed Wetlands (2000, October). *Guiding Principles for Constructed Treatment Wetlands: Providing for Water Quality and Wildlife Habitat.* Prepared for the U.S. EPA. Retrieved June 2, 2011, from http://water.epa.gov/type/wetlands/constructed/upload/guidingprinciples.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Magmedov, Vyacheslav (n.d.). Environment Probe, Back to Nature: Constructed Wetlands for Low-Cost Wastewater Treatment and Nature Conservation. Retrieved June 4, 2011, from http://www.constructedwetlands.org/cw/index.cfm.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Stormwater Wetland*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm.

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Storm Water Wetlands*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2007_05_29_mtb_wetlands.pdf.

U.S. EPA National Risk Management Research Laboratory, NRMRL (2000, September). *Constructed Wetlands Treatment of Municipal Wastewaters Manual.* Retrieved June 3, 2011, from http://water.epa.gov/type/wetlands/restore/upload/2004_12_20_wetlands_pdf_Design_Manual2000.pdf.

U.S. EPA (2006, May). *Stormwater Wetland*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=74&minmeasure=5.

U.S. EPA (2011, June). *Constructed Wetlands*. Retrieved June 3, 2011, from http://water.epa.gov/type/wetlands/restore/cwetlands.cfm.

Detention Systems: Dry Ponds

Potential Applications

The purpose of detention systems is to intercept a given volume of stormwater runoff for temporary storage and to allow a gradual release to the receiving environment or storm sewer system. Detention systems are on-line, end-of-pipe BMPs that provide settling of suspended particulates; however, resuspension of settled materials can potentially occur under future events. Dry ponds are designed to completely drain within a given period of time, typically 24 to 48 hours (Barr Engineering Co., 2001).

Brief Description

This BMP's primary focus is on water quantity control. However, when combined with other BMPs (as part of a treatment train, TT), enhancement options relating to water quality improvement present themselves. For colder climates, such as Utah, this BMP performs well. Quantity management techniques include peak flow reductions and decreased energy to downstream environments, thereby decreasing the potential for scouring and erosion. In addition to functionality, detention systems can serve as recreational areas and, like retention systems, can be applied early in development to manage site runoff during construction (Barr Engineering Co., 2003). See Figure 1 for a schematic of a dry pond.

Considerations

Prior to design, analysis of soils and depth to the bedrock and seasonally high groundwater table is necessary in order to determine applicability. Detention systems can service drainage areas greater than 10 acres, but area is only important for outlet sizing (to ensure no clogging occurs).

Purposes

Water Quantity

Flow attenuation	■
Runoff volume reduction	■

Water Quality

Pollution Prevention	
Soil erosion	◧
Sediment control (TT)	◧
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	N/A
Nitrogen (N)	N/A
Heavy metals	N/A
Floatables (ONLY with skimmer)	◧
Oil and grease	N/A
Fecal coliform	N/A
Biochemical Oxygen Demand (BOD)	N/A

Source: Barr Engineering Co., 2001

By increasing detention time, from 24 to 48 hours, the contaminant removal efficiency greatly improves, thereby increasing the serviced area size. Since water is detained, discharge temperatures are typically warmer than under natural circumstances; as a result, this BMP should not be applied in cold water sensitive areas. Recommended components include a sediment forebay, extended storage, a micropool at the outlet, alterations to the pond shape, to minimize short circuiting, and a low flow channel (UDFCD, 2010).

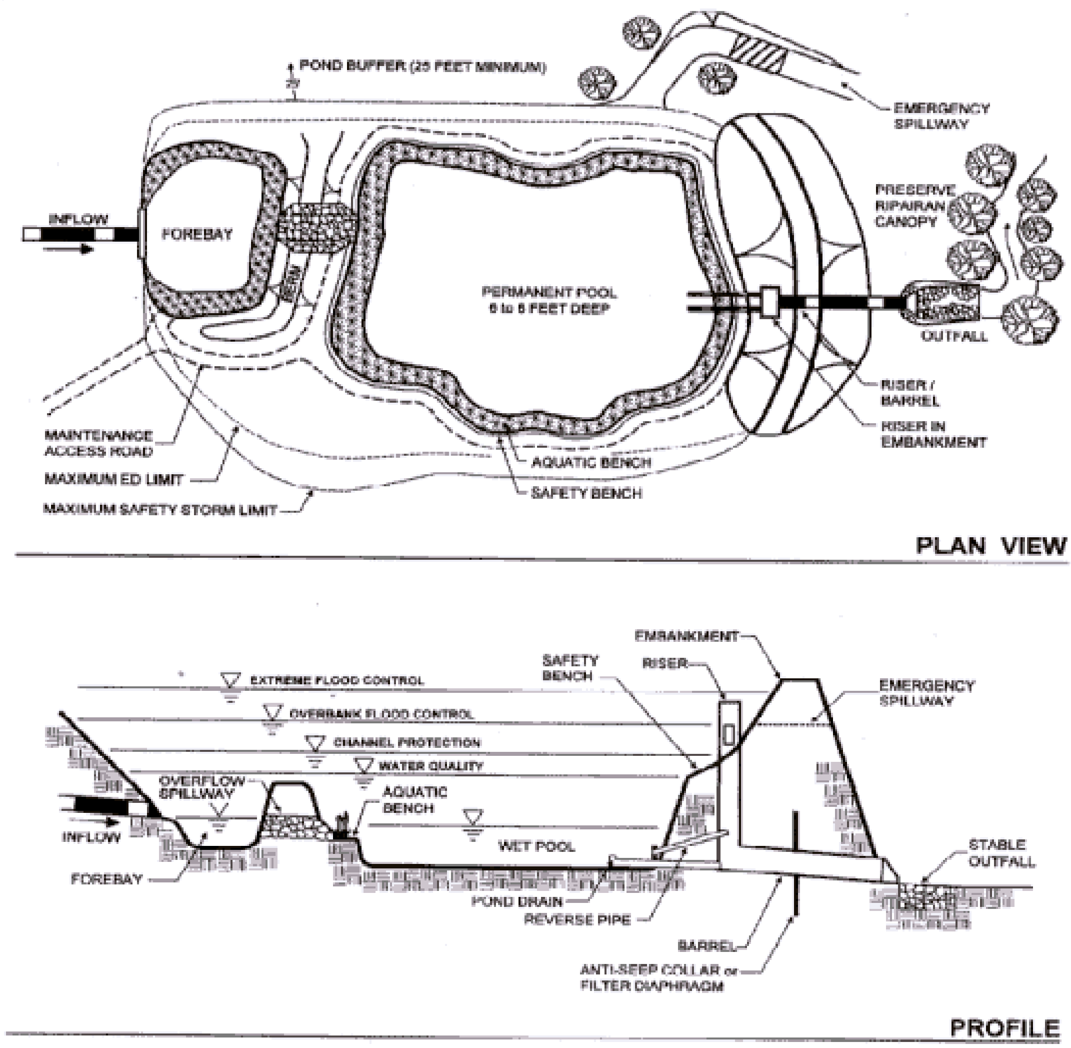


Figure 9: Plan and Profile Views of a Dry Pond (Source: SMRC, n.d.)

Potential drawbacks for such systems include the prevalence for clogging, sediment and trash accumulation, weed and invasive species growth, acrid smells, and approval from dam safety authorities (Barr Engineering Co., 2003). Despite being less expensive than wet detention basins, dry detention provides lower water quality benefits (City of Chattanooga, Town of Signal Mountain, and Hamilton County, 2008).

Design Guidelines

The following bullets outline the components of a dry pond, with additional, in-depth guidelines provided in the references list (City of Chattanooga, Town of Signal Mountain, and Hamilton County, 2008; Barr Engineering Co., 2001):

- Drainage area;
- Pond volume and water quantity control requirements;
- Detention time;
- Pond slopes;
- Length to width ratio;
- Live storage depth;
- Winter operation;
- Pond inlet/outlet structures and pipes;
- Low flow channels, only if forebay is not present;
- Scour control.

Maintenance Recommendations

Once the unit becomes established, the primary maintenance considerations should include (U.S. EPA, 2006):

- Regular inspection and correction, especially during and after spring runoff events, to ensure drainage system functionality, stability of bank slopes, sediment accumulation within the forebay, and vegetation health;
- Removal of trash twice annually from side slopes, embankments, and the emergency spillway;
- Sediment removal every 5 to 25 years, dependent upon the design sediment accumulation capacity (disposal of which must meet local, state, and federal regulations);
- Annual inspection that dry pond operates correctly under the design conditions.

Problems to look for include subsidence, erosion, cracking or tree growth on embankments, damage to the emergency spillway, sediment accumulation at the outlet, and erosion within the basin and on the banks. Regular inspections should also include detailed notes, in order to mark any changes to the dry pond and contributing watershed.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Extended Storage Ponds; Dry Ponds*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STDetDryPond.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 7.1: Dry Detention Basin (DDB).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/7.1ddb.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Dry Extended Detention Pond*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm.

U.S. EPA (2006, May). *Dry Detention Ponds*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=67&minmeasure=5.

Detention Systems: Dry Swales

Potential Applications

This BMP is applicable in areas where high sediment loads and large quantities of stormwater are generated, providing treatment and flow attenuation. Dry swales are good options for residential areas, located in drainage easements along a lot or roadside, and in replacing the curb-and-gutter system. However, the area's soils must meet a minimum permeability requirement in order to be valid. Dry swales are similar in design to wet ponds, differing only by the addition of an underdrain, which allows for complete drainage. This is the BMP of choice for small-area stormwater retrofit projects, facilitating residential and institutional areas of low to moderate density, or as parking lot islands. Additionally, as temperature of discharged stormwater is not majorly elevated, this BMP is applicable in cold water trout stream watersheds.

Brief Description

Dry swales are characterized as open, vegetated channels, mitigating both water quantity and quality issues. The focus of the design is on temporary water storage and slowing runoff velocities via a system of permeable check dams or ditchblocks, which increases sedimentation of suspended contaminants. Such BMPs should be treated as an extension of a residential lawn, potentially increasing the infiltration rates in addition to providing a habitat for wildlife. The presence of the underdrain system (gravel surrounding a perforated pipe) conveys infiltrated, treated water to the storm sewer system. This BMP is less expensive than a traditional, curb-and-gutter system, but requires closer attention to regular maintenance. For a schematic of a dry swale, see Figure 1.

Considerations

Prior to design, analysis of soils and depth to the bedrock and seasonally high groundwater table is necessary in

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	□

	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	■
Nitrogen (N)	■
Heavy metals	■
Floatables	□
Oil and grease	◧
Fecal coliform	□
Biochemical Oxygen Demand (BOD)	◧

order to determine applicability. In-situ soils should be highly permeable, with a minimum distance of three feet from the bottom of the unit to the seasonally high groundwater table. These are important considerations that ensure complete drying out of the system and no groundwater contamination. Individually, dry swales can only treat small (less than five acres), flat (slopes less than four percent) areas and must be designed and installed properly in order to be effective at sediment/pollutant removal. However, if slopes are steep, dry swales may be employed as long as they run parallel to the contours. Amending soils to a 30 inch depth with a sand-soil mix is necessary if in-situ soils are not viable.

Dry swales may not be applicable when driveway culverts or sidewalk extensions exist and are often subject to damage from off-street parking and snow removal methods.

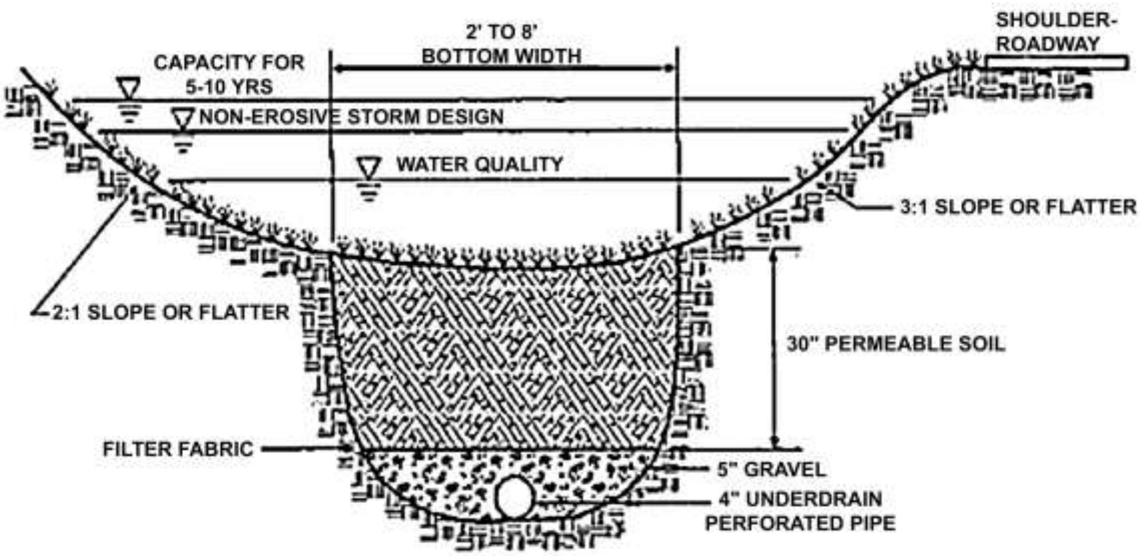


Figure 10: Dry Swale Cross Section (Cited by Barr Engineering Co., 2001, Source: Center for Watershed Protection, 2000)

Design Guidelines

The following general steps outline the components of a dry swale, with additional, in-depth guidelines provided by Schueler (1995) and the remainder of resources in the references list:

- Proper siting, via a site sensitivity analysis, to ensure functionality;
- Compute the water quality capture volume (WQCV) or the equivalent local requirement for precipitation detention;
- Channel profile and size (bottom width, depth, length, and slope), using site constraints (slopes, soil permeability) to maximize treatment (18 inch maximum ponding depth) and minimize short circuiting;
- Compute the WQV drawdown time, ensuring it's less than 24 hours;
- Compute, check, and adjust the two year and ten year frequency storms' peak discharges for erosive potential and volumetric capacity, respectively, on the unit;

- Provide a six inch minimum of freeboard above the ten year depth for safety;
- Design underdrain system, to allow for proper discharge and minimized ponding;
- Choose proper vegetation, such as native turfs and grasses, to enhance the biodiversity, habitat, and treatability.

The addition of a check dam forebay (approximately 25% of the WQV) between the inlet and main body will increase overall functionality and decrease maintenance requirements. Vegetation is imperative to dry swales' overall utility and, therefore, must be vigorous, rigid, upright, and salt/drought tolerant.

Maintenance Recommendations

Once established, the primary maintenance considerations should include:

- Regular inspection and maintenance of vegetation establishment and vigor, providing for reseeding or alternate plant species, erosion potentials, and accumulation of sediments and debris;
- Removal of trash and debris frequently, with excess sediment removal upon 25% accumulation at the swale bottom;
- Vegetation management includes mowing of turfs (to a four inch height) and native grasses in the early spring, weed/detritus removal, and rare use of fertilization (if necessary, apply phosphorous-free fertilizer only during cool spring or fall weather, when runoff is not expected within 14 days of application).

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Dry Swales*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STDetDrySwale.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 9.5: Filter Strips and Swales (FSS).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/9.5fss.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Schueler, Tom (1995, December). *Site Planning for Urban Stream Protection.* Center for Watershed Protection. Ellicott City, MD.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Grass Channel*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm.

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Vegetated Swales*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_vegswale.pdf .

U.S. EPA (2006, May). *Grassed Swales*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=75&minmeasure=5.

Infiltration Basins

Potential Applications

This BMP is typically applied as an end-of-pipe system that manages stormwater runoff resulting from multiple sites (two acres maximum), as opposed to single lot applications (i.e. on-site infiltration BMP). Generally, infiltration basins are only as effective as the design storm used to calculate its dimensions and, therefore, require pretreatment measures and additional downstream control systems. However, the downstream structures require much smaller sizes as a result of being a part of the BMP treatment train (Barr Engineering Co., 2001).

Such systems should not be applied near stormwater hotspots (industrial or commercial sites), areas contributing high contaminant loads, or where the seasonally high groundwater table has the potential to intercept the bottom of the system. In general, a three foot minimum separation between the system and the groundwater should be maintained at all times to prevent groundwater contamination.

Brief Description

This BMP is a stormwater runoff impoundment designed to capture, store, infiltrate, and treat (to varying extents of quality) stormwater runoff, draining completely over a period of days. The addition of dense, well-maintained vegetation is both necessary and a method of overall system enhancement.

Due to design constraints (based on a certain design storm size), this BMP works best as a part of a treatment train. This treatment train requires pretreatment, good housekeeping measures, public education, and additional downstream stormwater controls for storms exceeding the infiltration basin design capacity. See Figure 1 and

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	■
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	■
Nitrogen (N)	■
Heavy Metals	■
Floatables	◧
Oil and grease	◧
Fecal coliform	◧
Biochemical Oxygen Demand (BOD)	◧

Figure 2 for schematics of different applications of an infiltration basin.

Considerations

This BMP must maintain a three foot separation between the bottom of the system and the seasonally high groundwater table, at all times, in order to ensure no groundwater contamination occurs. In designing the system, the choice of design storm affects the overall functionality of the system and limits the extent of control measures. Infiltration basins are linked to high failure rates as a result of inadequate or neglected maintenance and improper siting and design, all of which can be prevented by following the proper design guidelines.

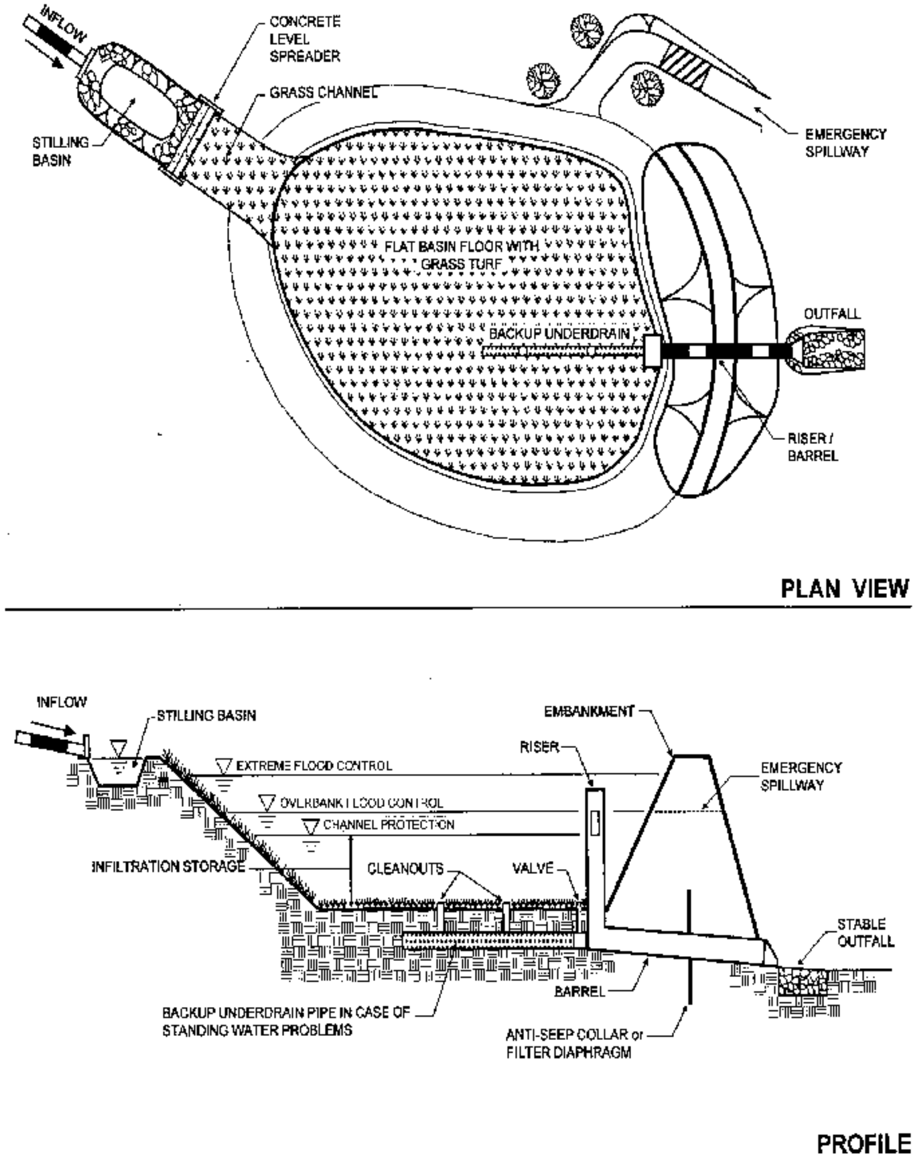


Figure 11: Schematic of an Infiltration Basin (Source: SMRC, n.d.)

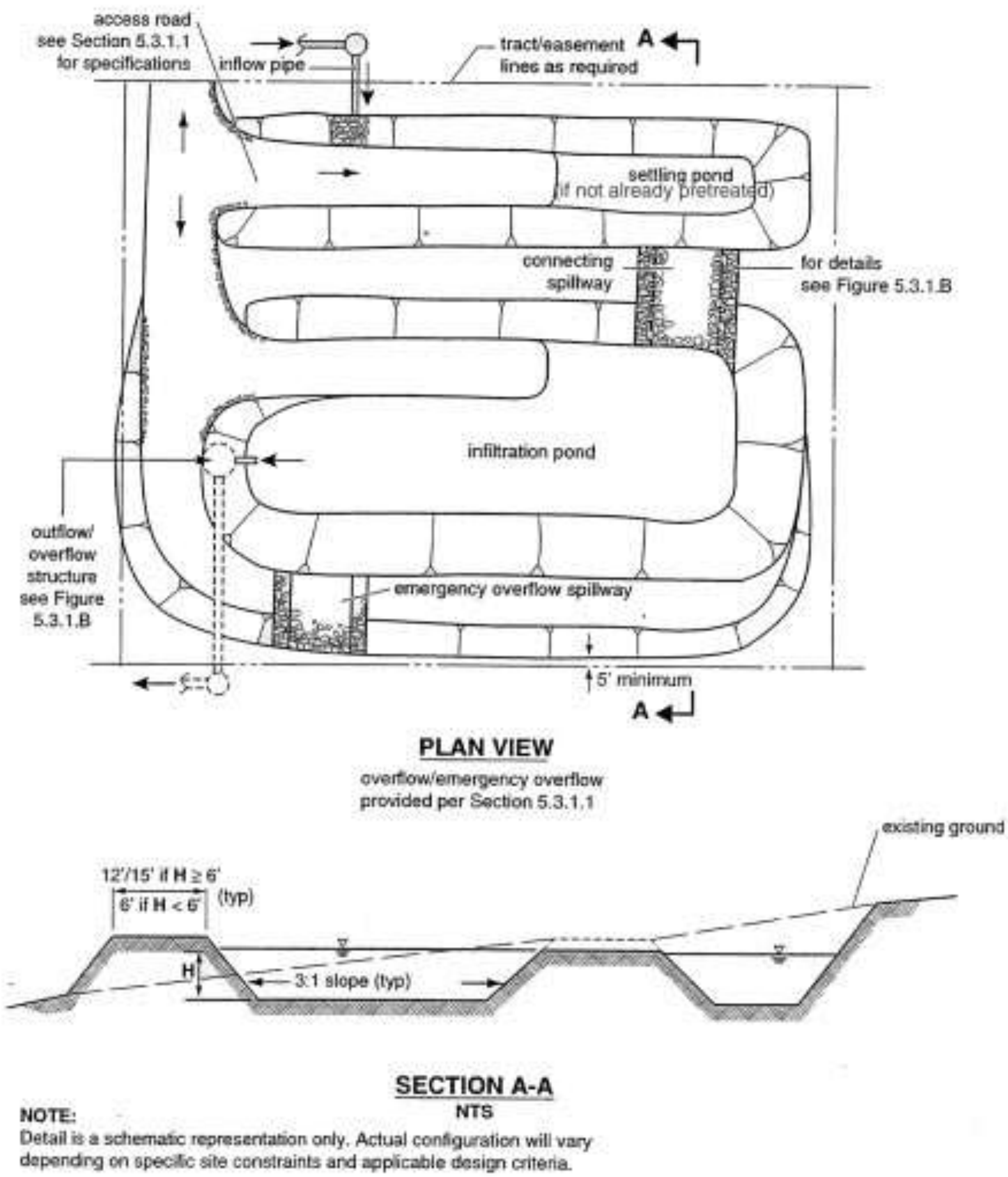


Figure 12: Infiltration Basin Schematic with Settling Pond (Cited by Barr Engineering Co., 2003; Source: Schueler, 1987)

Design Guidelines

It is important that, prior to any design or construction activity, a site sensitivity analysis be carried out. This analysis will determine:

- Soil conditions and potential effects on groundwater
- Runoff water quality
- Degree of detail required, based on the size and requirement(s) of the unit
- Geologic sensitivity

- Depth to groundwater table and bedrock
- Proximity to drinking water wells and building foundations
- Soil infiltration rates
- Size of the drainage area

For specific design considerations, refer to the provided list of resources. The following is a list of the general design parameters for infiltration basins:

- Design volume
- Off-line placement
- Pretreatment
- Infiltration rate
- Duration of ponding
- Average depth
- Basin geometry (slope H:V ratio maximum of 3:1 and shape L:W ratio minimum of 3:1)
- Vegetation
- Inflow and bypass structures
- Overflow structure
- Groundwater mounding potential
- Cold weather conditions

Maintenance Recommendations

Inspection and maintenance (i.e. cleaning out) of the pretreatment unit should occur twice annually (minimum), with inspections occurring every other month. Inspection of the main system, ideally after every major storm during the first months post-completion, should focus on sediment accumulation, erosion of the floor, duration of ponding, rip-rap conditions, and vegetative health. Where vegetation is present, monthly weeding is required throughout the first two growing seasons, decreasing to twice to three times per season thereafter.

References

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Infiltration Basins*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STInfilBasins.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and

Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Schueler, T. (1987). *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Metropolitan Washington Council of Governments, Washington, D.C.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Infiltration Basin*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

U.S. EPA (2006, May). *Infiltration Basin,* as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=69&minmeasure=5 .

Infiltration Trenches

Potential Applications

This BMP is similar to the practice of on-site infiltration (i.e. soakaway pits) and functions by intercepting overland flows generated by impervious surfaces. However, unlike on-site systems, infiltration trenches offer larger scale management, providing runoff collection for more than one lot or property. Since infiltration trenches provide both water quantity and quality control (for precipitation events not exceeding the design storms) through the means of infiltration, it is imperative that such systems not be applied near commercial, industrial, and stormwater hotspot sites. As with infiltration basins, this BMP functions most efficiently when as part of a suite of stormwater control methods.

Brief Description

Infiltration trenches are shallow excavations (three to twelve feet deep), lined with filter fabric, filled with granular media, and positioned to capture the maximum amount of runoff resulting from a drainage area and given design storm. Percolation rates of in-situ soils are much more important in this BMP system, versus infiltration of the unit itself, since these govern the rate at which stormwater runoff is managed. Refer to Figure 1 for a schematic of an infiltration trench.

Similar to infiltration basins, pretreatment is necessary for effective, long-term functionality, with additional downstream control measures required, since water quantities exceeding the design storm volumes can not be controlled.

Considerations

This BMP must maintain a three foot separation between the bottom of the system and the

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	■
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	■
Nitrogen (N)	■
Heavy Metals	■
Floatables	◧
Oil and grease	◧
Fecal coliform	◧
Biochemical Oxygen Demand (BOD)	◧

seasonally high groundwater table, at all times, in order to ensure no groundwater contamination occurs (Barr Engineering Co., 2001). In designing the system, the choice of design storm affects the overall functionality of the system and limits the extent of control measures. Infiltration trenches are linked to high failure rates as a result of inadequate or neglected maintenance and improper siting and design, all of which can be prevented by following the proper design guidelines. Inclusion of pretreatment and bypass components are necessary to ensure longevity and functionality.

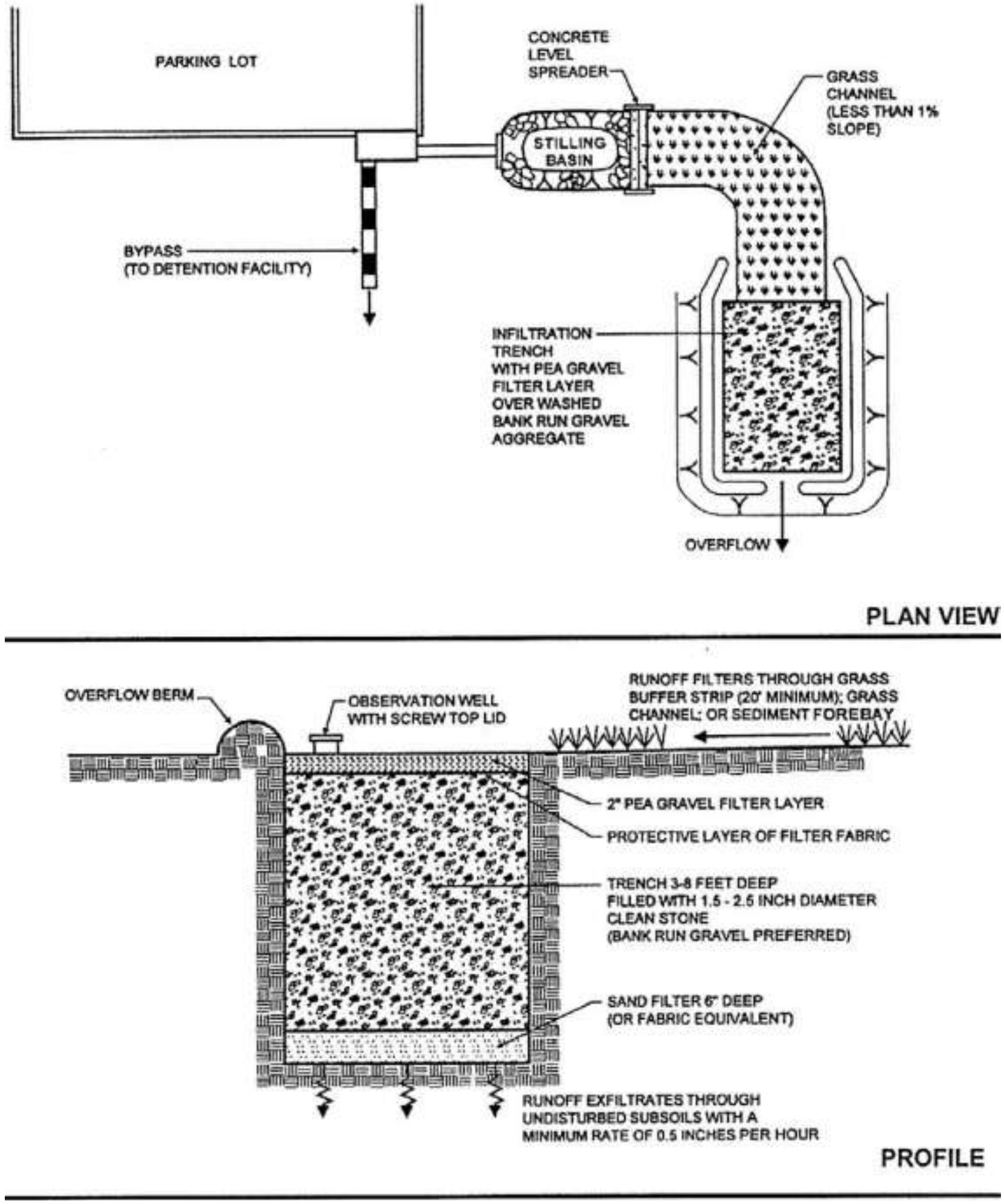


Figure 13: Plan and Profile View of an Infiltration Trench (Cited by U.S. EPA, 2006; Source: MDE, 2000)

Design Guidelines

It is important that, prior to any design or construction activity, a site sensitivity analysis be carried out. This analysis will determine:

- Soil conditions and potential effects on groundwater
- Runoff water quality

- Degree of detail required
- Geologic sensitivity
- Depth to groundwater table and bedrock
- Proximity to drinking water wells and building foundations
- Soil infiltration and percolation rates
- Size of the drainage area

For specific design considerations, refer to the provided list of resources. The following is a list of the general design considerations for infiltration trenches:

- Design volume
- Ponding duration
- Site soil permeability
- Trench volume and configuration
- Filter fabric
- Storage media
- Observation well
- Pretreatment
- Bypass structure
- Groundwater mounding potential
- Cold weather conditions

Maintenance Recommendations

Pretreatment unit maintenance will provide decreased trench maintenance needs, via the regular inspection and removal of accumulated sediments within the pretreatment basin (every two months and twice yearly, respectively). Inspections of the trench, after every major storm during the first months of establishment, will ensure proper stabilization and functionality of the unit, increasing to twice a year thereafter. Inspections should focus on accumulated sediments, leaves, and debris, inlet/outlet clogging, and if ponded water exists in the trench long after a storm.

If persistent ponding occurs, corrective maintenance (cleaning and replacement of media) is required for either the internal components of the system or the surface of the system. Internal mechanisms can be observed with the observation well or if ponding duration exceeds that allowed by the design.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Infiltration Trenches*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STInfilTrenches.pdf

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Infiltration Trench*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Infiltration Trench*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_infltrenc.pdf

U.S. EPA (2006, May). *Infiltration Trench*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=70&minmeasure=5

On-Site Infiltration

Potential Applications

This BMP is most effectively applied to small scale, individual lots (less than 0.5 acres in size), as off-line or retrofit systems (Barr Engineering Co., 2001). On-site infiltration units are capable of receiving sheet flow runoff from impervious, urban areas. Techniques to promote on-site infiltration include: (1) reduced lot grading, (2) soakaway pits, and (3) bioretention systems (see the section provided on "bioretention systems" for specific details). These techniques greatly reduce the size and cost of downstream control facilities. However, such BMPs should not be applied to areas near stormwater hotspots, such as gas stations, or high TSS load areas.

Reduced lot grading is viable if a lot is naturally flat; however, if land is undulating, minimal alterations to topography are allowed following local municipal guidelines. Soakaway pits are designed to receive runoff resulting from individual, impervious areas, such as roofs or small parking lots.

Brief Description

Since the focus is on serving small areas, the primary function of this BMP is to mitigate the normal impacts of urbanization on the natural water balance, via capture and infiltration of stormwater. This runoff is then used as an on-site resource, as opposed to allowing it to continue downstream. On-site infiltration mainly provides water quantity control benefits; however, through the addition of vegetation and the action of infiltration, water quality control benefits can be greatly enhanced. Reduced lot grading promotes infiltration by slowing the stormwater runoff that originates from impervious areas, such as roofs and yards. Soakaway pits are small, excavated depressions, which are backfilled with a porous media,

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	■
	Water Quality
Pollution Prevention (via Soakaway Pits)	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal (via Soakaway Pits)	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	■
Nitrogen (N)	■
Heavy Metals	■
Floatables	◧
Oil and grease	■
Fecal coliform	◧
Biochemical Oxygen Demand (BOD)	◧

and serve to enhance a site's infiltration of applied stormwater runoff.

Considerations

This BMP will successfully manage small drainage areas, typically less than 0.5 acres. A drain time of 24 to 48 hours is typically required in order to deter ponding of water aboveground. Prior to construction and design, a site sensitivity analysis should be carried out, in order to ensure that proper separation (three feet) is maintained between the bottom of the BMP and the seasonally high groundwater table. This is done to ensure groundwater contamination will not occur. In addition, this analysis will determine the appropriateness of a soakaway pit, since they are constrained by soil type, contributing drainage area, depth to bedrock, and depth to groundwater.

Design Guidelines

For specific design instructions, see the list of resources. The following general components should be considered when designing for reduced lot grading:

- Follow the necessary steps to prevent foundation drainage problems, obeying local municipal standards, and to increase both the storage and infiltration rates on-site
- Avoid the compaction of soils and improve infiltration by tilling to a depth of one to two feet or mixing the native soil with manure or compost
- Maintain native soil profiles as much as possible, to retain the natural hydrologic regime

It is important that, prior to any design or construction activity, a site sensitivity analysis be carried out. This analysis will determine:

- Soil conditions and potential effects on groundwater
- Runoff water quality
- Degree of detail required
- Geologic sensitivity
- Depth to groundwater table and bedrock
- Proximity to drinking water wells and building foundations
- Soil infiltration and percolation rates
- Size of the drainage area

For specific design considerations, refer to the provided list of resources. The following is a list of the general design considerations for on-site infiltration:

- Design volume
- Ponding duration
- Site soil permeability
- Trench volume configuration
- Filter fabric

- Storage media
- Observation well
- Pretreatment
- Bypass structure
- Groundwater mounding potential
- Cold weather conditions
- Gutter screens

The following general components should be considered when designing soakaway pits:

- Follow the necessary steps to prevent foundation damage, following local municipal standards
- Designing for a minimum storage area equivalent to two inches of water multiplied by the impervious area
- Designing for a maximum storage area equivalent to eight inches of water multiplied by the impervious area, without allowing overflow

Maintenance Recommendations

For soakaway pits, the removable filter in the roof leader should be cleaned regularly. Cleaning of filters should ideally occur after each major storm. When frequent overflows occur, replacement of the filter may be necessary.

Pretreatment unit maintenance will provide decreased channel maintenance needs, via the regular inspection and removal of accumulated sediments within the pretreatment basin (every two months and twice yearly, respectively). Inspections of the unit, after every major storm during the first months of establishment, will ensure proper stabilization and functionality, decreasing to twice a year thereafter. Inspections should focus on accumulated sediments, leaves, debris, inlet/outlet clogging, and whether ponded water exists in the channel long (in exceedance of the design time of 24 to 48 hours) after a storm.

If persistent ponding occurs, corrective maintenance (cleaning and replacement of media) is required for either the internal components of the system or the surface of the system. Internal mechanisms can be observed with the observation well or if ponding duration exceeds that allowed by the design.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: On-Lot Infiltration*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STInfilOnLot.pdf

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: On-Lot Treatment*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/

U.S. EPA (2006, May). *On-Lot Treatment*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=81&minmeasure=5

Rainwater Harvesting

Potential Applications

This BMP is typically applied individually, in residential and commercial applications, and provides water quantity control in highly developed, impervious areas. However, as rainfall availability is the driving factor of this BMP, such applications may not be a viable option for urban or suburban stormwater management in semi-arid and arid environments, such as Utah. The components necessary for rainwater harvesting include: (1) a rainwater collection surface, such as a rooftop; (2) a rainwater storage unit, such as a barrel or cistern; and, (3) a distribution system.

Brief Description

Rainwater harvesting involves the capture of stormwater runoff, resulting from an impervious surface such as a rooftop, and using the captured water to promote conservation, lower water bills, and reduce runoff. Together, these aid in reducing the chances of local flooding and lessening the landscaping/property management needs. However, since rainfall availability is the driving factor of such systems, analysis of annual amounts and precipitation patterns should be carried out.

Considerations

Rainwater harvesting, now legalized in the state of Utah, provides for residential lots to capture rainwater via either (1) 2, 100 gallon (maximum) rain barrels, or (2) 1, 2500 gallon (maximum) cistern. This law maintains that individual rainwater harvesting is legal only if priority downstream beneficial uses are successfully met (Utah State Legislature, 2011). Analysis of rainfall patterns should be analyzed in order to determine feasibility of rainwater harvesting as a BMP.

Purposes

	Water Quantity
Flow attenuation	■
Runoff volume reduction	■
	Water Quality
Pollution Prevention	
Soil erosion	◧
Sediment control	□
Nutrient loading	□
Pollutant Removal	
Total Suspended Sediment (TSS)	□
Total Phosphorous (TP)	□
Nitrogen (N)	□
Heavy metals	N/A
Floatables	□
Oil and grease	N/A
Fecal coliform	N/A
Biochemical Oxygen Demand (BOD)	N/A

Design Guidelines

Rainwater harvesting is a factor of local rainfall patterns, collection area, allowable collection volumes, and on-site uses. For the state of Utah, it is important that further analysis of widespread rainwater harvesting be analyzed, in order to determine whether the overall consequences outweigh those of the individual, or vice versa. For site specific details, impervious area (i.e. rooftop) will determine the size of storage, in addition to the site's needs, such as landscaping a small garden to irrigating an entire lawn. As there are several commercial vendors for rainwater harvesting supplies, design specifications can be obtained through them. For a generalized visualization of a residential application, see Figure 1.

Figure 1: Rainwater Harvesting Components for a Typical, Residential Application (Source: Jones & Hunt, n.d.)

Maintenance Recommendations

Rainwater harvesting systems are typically hands-off, stand-alone systems and any maintenance recommendations, pertinent to the particular system used, should be obtained via the supplier. However, in general, vector control (i.e. mosquitoes) and winterization of the unit should be considered annually.

References/Sources

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Jones, M. P. and Hunt, W. F. (n.d.). *Urban Waterways - Rainwater Harvesting: Guidance for Homeowners*. Retrieved June 1, 2011, from http://www.bae.ncsu.edu/topic/waterharvesting/Residential-Rainwater-Harvesting.pdf.

Stormwater Manager's Resource Center, SMRC (n.d.). *Pollution Prevention Fact Sheet: Rain Barrels*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Texas Commission on Environmental Quality, TCEQ (2007, January). *Rainwater harvesting Guidance for Public Water Systems.* Retrieved June 2, 2011, from http://rainwaterharvesting.tamu.edu/drinking/rg-445_1985136.pdf.

Texas Water Development Board (2005). *The Texas Manual on Rainwater Harvesting, Third Edition.* Retrieved June 2, 2011, from http://www.twdb.state.tx.us/publications/reports/rainwaterharvestingmanual_3rdedition.pdf.

Utah State Legislature (2011). *Utah Code Title 73, Chapter 3, Section 1.5: Water and Irrigation, Appropriation, Capture and storage of precipitation*. Retrieved June 4, 2011, from http://le.utah.gov/~code/TITLE73/htm/73_03_000105.htm.

Retention Systems: Wet Ponds

Potential Applications

Comprised of an on-line, end-of-pipe constructed stormwater pond that retains a permanent volume of water. Provides suspended pollutant removal through sedimentation and dissolved pollutant removal through a combination of physical, chemical, and biological methods. Provide a moderate to high capacity for treating urban runoff, depending on the volume ratio of the permanent pool to the applied runoff. For either single-purpose (water quality) or in-tandem (water quantity) use for residential, commerical, and industrial sites. Local authorities and groundwater regulations must be consulted prior to construction (City of Chattanooga, Town of Signal Mountain, and Hamilton County, 2008).

Brief Description

Typically designed as shallow, vegetated catchment areas that receive stormwater runoff resulting from nearby impervious surfaces (such as parking lots). The stormwater enters the unit, is allowed to pond at the surface, and gradually infiltrates into the soil/substrate layer. The focus of wet ponds is on small storm hydrology, with larger storms being allowed to flow through or be diverted directly to the storm drain system. Application of wet ponds early in the development stages ensures treatment of construction runoff as well. For schematics of wet ponds, see Figure 1 and Figure 2.

Considerations

Prior to design, analysis of soils and depth to the bedrock and seasonally high groundwater table is necessary in order to determine applicability.

Purposes

Water Quantity

Flow attenuation	■
Runoff volume reduction	□

Water Quality

Pollution Prevention

Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A

Pollutant Removal

Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy metals	◧
Floatables (only with skimmer)	■
Oil and grease	◧
Fecal coliform	◧
Biochemical Oxygen Demand (BOD)	◧

In order to increase pollutant removal, the following steps should be considered (Barr Engineering Co., 2001):

- Varied depths within the permanent pool
- Sediment forebay, for ponds exceeding 4000 square feet, with a length to width ratio of 2:1 and area equivalent to 10-25% of the surface area
- Pond shape with a length to width ratio of 3:1 and a minimum pool surface area of 0.25 acres
- Multi-stage outlets, meeting local conditions and regulations
- Chemical treatment, to enhance flocculation
- Establishment of aquatic vegetation, for enhanced treatability and aesthetics

In a cold climate, such as Utah, lower temperatures will reduce the biological activity and, therefore, decrease the derived quality benefits. In addition, during spring runoff, design-exceeding volumes can carry sediment downstream; thus, incorporation of additional extended pond storage capabilities may be necessary.

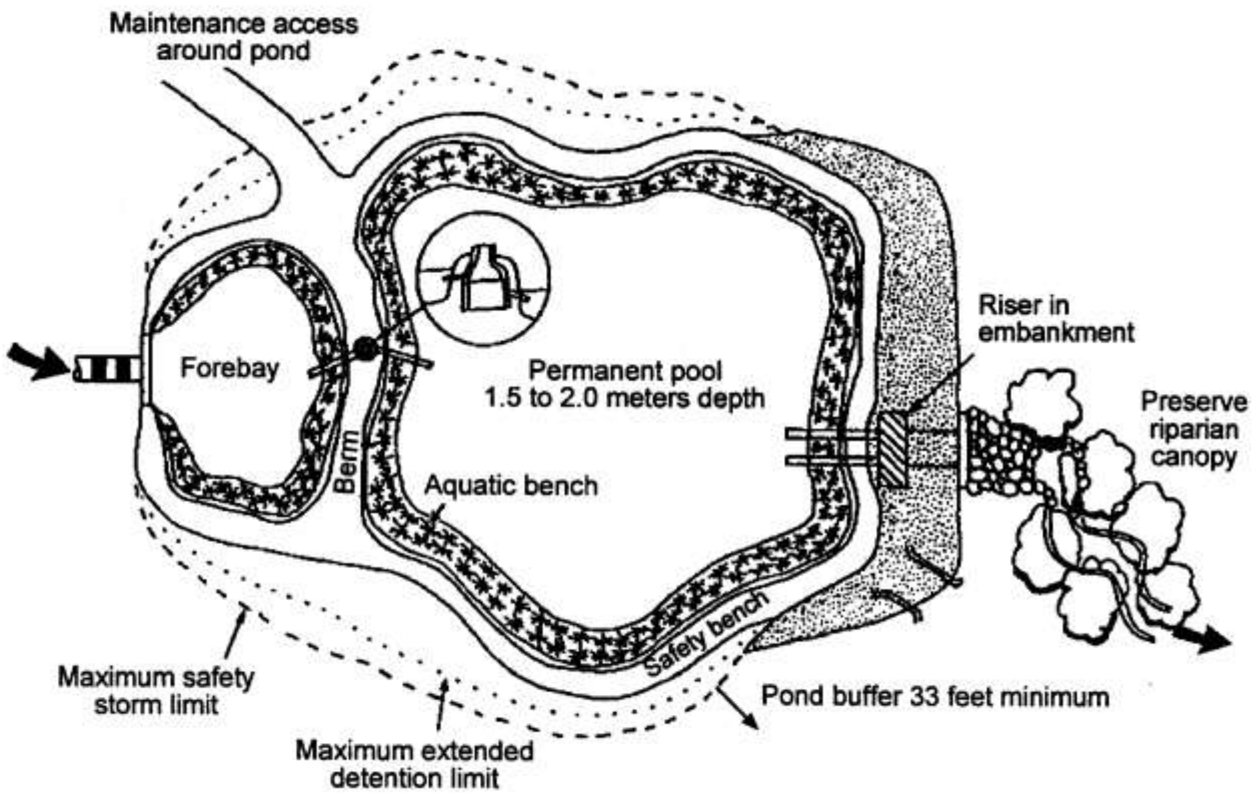


Figure 14: Plan View of a Wet Pond (Cited by Barr Engineering Co., 2003; Source: Schueler, 1987)

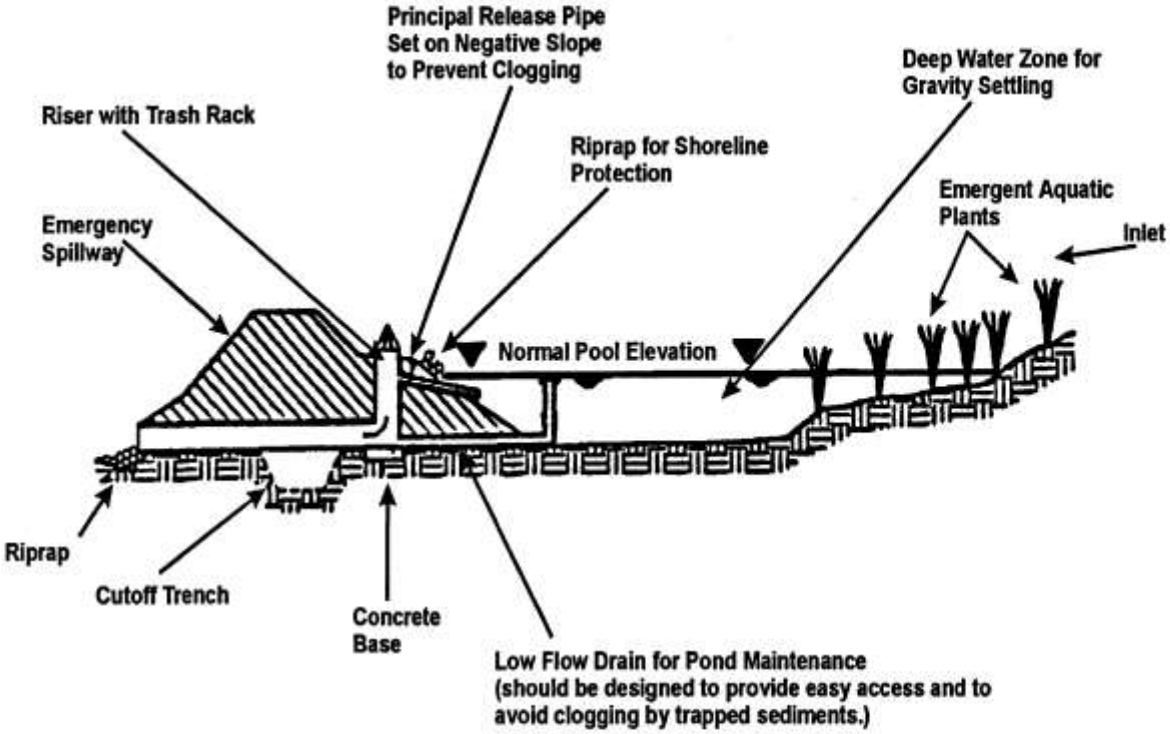


Figure 15: Profile View of a Typical Wet Pond (Cited by Barr Engineering Co., 2003; Source: Maryland Department of Environment, 1986)

Design Guidelines

Sufficient pond volumes are required for proper functioning of the BMP, servicing watersheds from ten acres to one square mile in size; however, if adequate groundwater flow is present, then sites smaller than ten acres may be suitable.

The following general steps outline the components of a wet pond, with additional, in-depth guidelines provided in the references list (Barr Engineering Co., 2001):

- Pond volume;
- Surface area;
- Pond depth;
- Avoidance of short-circuiting and promotion of plug flow;
- Pond slopes;
- Sediment management, via sediment storage design;
- Pond inlet/outlet structures and pipes;
- Scour control;
- Water quantity control requirements, focusing on winter and spring runoff considerations.

Maintenance Recommendations

Prior to establishment, a long-term water quality monitoring program is essential to ensuring that anoxic zones do not arise and that stratification does not occur. Once established, the primary maintenance consideration should include (U.S. EPA, 1999):

- Regular inspection and correction, especially during and after spring runoff events, to ensure drainage system functionality, stability of bank slopes, and vegetation health;
- Removal of trash twice annually and removal of accumulated sediments every five to 25 years, which is dependent upon the sediment accumulation capacity incorporated into the design (disposal of which should meet local, state, and federal regulations);
- Vector control (i.e. mosquitoes).

Problems to look for include: subsidence, erosion, cracking or tree growth on embankments, damage to the emergency spillway, sediment accumulation at the outlet, and erosion within the basin and on the banks. Regular inspections should also include detailed notes, in order to mark any changes to the wet pond and contributing watershed.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Wet Ponds*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STRetenWetPond.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 7.3: Wet Detention Basin (WDB).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/7.3.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Wet Pond*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm.

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Wet Detention Ponds*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_wetdtnpn.pdf .

U.S. EPA (2006, May). *Wet Ponds*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=68&minmeasure=5.

Soil Erosion Control

Potential Applications

This BMP uses structural methods to provide both permanent and temporary erosion control. Three methods, discussed herein, include rip-rap, permanent diversion structures, and temporary diversion structures. These methods are relatively inexpensive to construct and are effective at reducing erosion and subsequent sediment transport; however, temporary structure removal may pose challenges (Price and Karesh, 2002).

Brief Description

Rip-Rap: Permanent Method

Typified by heavy, large-diameter stones placed near the inlets and outlets of pipes and channels, with the purpose of erosion protection in areas experiencing concentrated flows, turbulence, or wave energy. This erosion control type functions by reducing velocities to allowable levels. For outlets with appropriately low velocities, a structural apron lining can be used; otherwise, a stilling or impact basin may be used. These rip-rap lined, reinforced concrete basins are used to collect and dissipate high velocities prior to discharge. Rip-rap is most suitable for sites greater than five acres, for channels experiencing velocities exceeding four feet per second (fps), and instances where grass-lined channels are not possible (Barr Engineering Co., 2001).

Permanent Slope Diversion

Typically a channel and dike constructed across a slope, used to intercept runoff and direct it to stabilized outlets (at reduced velocities), away from erosive areas. Diversions serve to increase flow path length and reduce the slope, thereby decreasing velocities and erosion capabilities. This control type

Purposes

	Water Quantity
Flow attenuation	N/A
Runoff volume reduction	N/A
	Water Quality
Pollution Prevention	
Soil erosion	■
Sediment control	■
Nutrient loading	■
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	◧
Nitrogen (N)	N/A
Heavy metals	N/A
Floatables	N/A
Oil and grease	N/A
Fecal coliform	N/A
Biochemical Oxygen Demand (BOD)	N/A

is effective for steep or long slopes and dependent on both the length of the slope and the soil type.

Temporary Slope Diversion

Constructed across slopes above disturbed areas and consisting of several methods, including: a ridge of compacted soil; a channel; a flexible conduit (i.e. polyethylene pipe); or, any combination. Like permanent diversions, they prevent erosion by directing runoff away from unprotected slopes to a stabilized outlet. In addition, they can convey runoff with high sediment loads to a sediment-trapping structure. They are effective at reducing high flows and preventing rill and gully erosion. Can be used in place of silt fences, providing for decreased maintenance and higher, long-term efficiency.

Design Guidelines

Rip-rap

Depending on the scope and complexity, a detailed design may not be required for inlet and outlet protection; however, situations concerning very high velocities or very low tailwater conditions should be designed by a qualified engineer. For site planning considerations and design guidelines, please refer to Chapter 6, Section H of the *Soil Erosion and Sediment Control Handbook* (USDASCS & RIDEM, 1989).

Permanent Slope Diversion

Capacity should provide suitable protection for the area of concern, with provision of freeboard, which is the extra depth above the design depth (margin of safety). Cross sections may be parabolic, V-shaped, or trapezoidal, but side slopes must fall below the stable slope associated with the site's soil. Last, if mowing of the diversion is required, side slopes should not exceed 3:1 (horizontal:vertical) (Barr Engineering Co., 2001).

Temporary Slope Diversion

Capacity is based on maximum drainage area (five acres) as opposed to storm frequency. Channel grades of less than two percent should be stabilized with erosion control blankets, while grades exceeding two percent may require turf-reinforcement mats. If flow velocities exceed nine fps, rock rip-rap or turf reinforcement should be considered. The design should maintain a height of 1.5 feet above the channel, with side slopes of 2:1 or flatter. If runoff is free of sediments, it can be released through a stabilized outlet; however, if runoff contains high sediment loads, it must be directed to a sediment-trapping device.

Maintenance Recommendations

Regular/Frequent

- Inspection of rip-rap after major storms, with replacement of damaged portions as soon as possible
- If rip-rap damage occurs repeatedly in a particular area, site design and original conditions must be reassessed
- Inspection of permanent vegetation, especially during establishment, and repaired as necessary
- Inspect diversion dikes *weekly* and after rainfall events, focus on removal of sediment from flow area and repairs
- Inspect outlets and diversions, making sure to prevent gully formation, scouring, bank failure, breaching, and other damages

Regular/Infrequent

- Removal of sediments and revegetation in areas of buildup within permanent structure
- Inspect right-of-way diversions for wear and tear after heavy rainfall events
- Once temporary structures are no longer necessary, remove and fill the channel to blend with the natural topography and appropriately stabilize the disturbed area

Annual

- Inspection of rip-rap, with replacement of damaged portions as soon as possible

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Mulches, Blankets and Mats*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPSoilMulch.pdf.

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Structural Methods*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPSoilStructural.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Price, J. C. and Karesh, R. (2002, March). *Tennessee Erosion & Sediment Control Handbook*: *A Guide for Protection of State Waters through the use of Best Management Practices during Land Disturbing Activities*. Retrieved June 1, 2011, from http://www.state.tn.us/environment/wpc/sed_ero_controlhandbook/.

Stormwater Manager's Resource Center, SMRC (n.d.). *Erosion and Sediment Control Fact Sheets*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

U.S. Department of Agriculture Soil Conservation Service, USDASCS, and Rhode Island Department of Environmental Management, RIDEM (1989). *Rhode Island Soil Erosion and Sediment Control Handbook*. Retrieved June 3, 2011, from http://www.dot.ri.gov/documents/enviro/stormwater/Soil_Erosion_Sediment_Control_Handbook.pdf.

U.S. EPA (2006, May). *Riprap*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=39&minmeasure=4.

Check Dams

Potential Applications

This BMP can be applied as either a temporary or permanent control measures in high concentrated flow areas, such as vegetated ditches or swales; however, it should *not* be used in streams or creeks. Check dams should be used in conjunction with erosion control blankets, in order to ensure establishment and stabilization of vegetated side slopes, the ditch bottom, and the shoreline. Recommended for use in areas of stormwater flow, with a focus on: slowing the flow, pooling the runoff, and releasing at a controlled rate, all while providing water quality treatment.

Brief Description

This system serves to prevent erosion and promote sedimentation of high sediment load stormwater runoff, via slowing flow velocities and/or by filtering concentrated flows. Constructed from numerous materials *excluding* staked hay bales and silt fences, check dams can successfully manage a wide range of flows. They function best as a coarse- and medium-sized particle removal system, with little ability to retain fines. In combination with erosion control blankets, this BMP can provide:

- Soil stabilization
- Enhanced vegetative growth
- Soil shielding from erosive conditions

Considerations

Such systems require periodic repair and sediment removal upstream of the check dam, despite initial low costs and ease of construction. Concerning construction, staked hay bales and silt fences should

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	◧
	Water Quality
Pollution Prevention	
Soil erosion	■
Sediment control	■
Nutrient loading	◧
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy Metals	◧
Floatables	◧
Oil and grease	□
Fecal coliform	□
Biochemical Oxygen Demand (BOD)	◧

not be used due to failures and ineffective behavior. If a system is temporary, removal can be difficult.

Design Guidelines

The systems are meant to serve as impediments to high stormwater flows and, therefore, the design should consider the addition of a shallow pool upstream of each check and erosion control blanket. Rock check dams should consist of well-graded stone consisting of a mixture of rock sizes. Though design specifics are not listed within this appendix, the sources provided offer several helpful documents.

Maintenance Recommendations

Since such systems focus on removing suspended contaminants, particularly sediments, the removal of settled material is necessary to the BMP's life and functionality. Therefore, the primary maintenance considerations include:

- Inspection and correction of check dams and drainageways, after each runoff event, in order to maintain design specifications, such as height, cross-section geometry, and flow-through regimes
- Anticipation of submergence and deposition above the check dam and erosion around the dam edges under high flows
- Removal of accumulated sediments behind the dams, as needed, to ensure prevention of channel vegetation damage, continual drainage through the stone check dam, and prevention of large flows carrying sediments over the dams and downstream

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Check Dams*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPSedCheckdam.pdf

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 4.1: Check Dam (CD).* Retrieved June 2, 2011, from

http://www.hamiltontn.gov/waterquality/bmps/4.1cd.pdf

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

U.S. EPA (2006, May). *Check Dam*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=36&minmeasure=4

Dikes, Berms, and Swales

Potential Applications

These BMPs are useful in the treatment of waters that possess high concentrations of suspended contaminants, such as sediments, and when needing to bypass areas whose soils possess high erosion probabilities, in order to prevent degradation of the water body.

Brief Description

These systems allow for diversion of sediment-impaired waters to be either treated via a device, such as a sediment basin or sediment trap, or to bypass areas with soils deemed to be sensitive to high erosion.

Considerations

Size, in terms of width, is a concern for these systems, with space limitations typically restricting their implementation.

Attention should be paid to underlying soils, which, if permeable, can facilitate infiltration in addition to the primary measure of diversion of storm water runoff. Additionally, if infiltration is desired, incorporating vegetation is known to enhance this secondary process (SMRC, n.d.).

Design Guidelines

The systems are meant to serve as conveyance mechanisms and, therefore, generally include a sediment trap or sediment basin for reduction of

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	◧
	Water Quality
Pollution Prevention	
Soil erosion	◧
Sediment control	◧
Nutrient loading	◧
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy Metals	◧
Floatables	◧
Oil and grease	◧
Fecal coliform	◧
Biochemical Oxygen Demand (BOD)	◧

suspended contaminants. Though design specifics are not listed within this appendix, it is generally accepted that earthen dikes possess a height of approximately two feet and be hydroseeded to promote stabilization.

In designing such systems, it is required the systems be able to manage the storm water runoff resulting from a ten year storm event. In order to reduce erosion, the following methods, highlighting increased channel roughness, should be considered (City of Chattanooga, Town of Signal Mountain, and Hamilton County, 2008):

- Rock lining of slopes and banks;
- Spreading of mulch and seed;
- Stone check dams.

Maintenance Recommendations

Since such systems focus on removing suspended contaminants, particularly sediments, the removal of settled sediments is necessary to the BMP's life and functionality. Therefore, the primary maintenance considerations include:

- Removal of settled sediments from systems' base levels;
- Removal of settled sediments from the systems' outlet works;
- Mitigating erosion of slopes and banks.

References/Sources

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 9.5: Filter Strips and Swales (FSS).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/9.5fss.pdf

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

Stormwater Manager's Resource Center, SMRC (n.d.). *Erosion and Sediment Control Fact Sheets: Dikes, Berms, and Swales.* Retrieved June 3, 2011, from

http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool5_ESC/ESC%20FS3.pdf

Oil/Grit Separators

Potential Applications

Since oil/grit separators provide little water quality or quantity management as a standalone system, this BMP is best used as a pretreatment device in conjunction with other BMPs. It is highly recommended for retrofit situations and for commercial, industrial, and transportation types of land use; however, some small urban lots can be accomodated. Pollutant removal focuses on sediments and hydrocarbon loadings resulting from impervious surfaces, preferably limited to one acre in size. This is an off-line BMP, with the potential for both pre-manufactured and cast-in-place units.

Brief Description

Oil/Grit separators are BMPs designed to remove trash, debris, sediments, and oil and grease contaminants from stormwater runoff via sedimentation of particulates and phase separation for immiscibles. However, this BMP must *not* be used to remove dissolved/emulsified oils. Due to minimal water quality and quantity control benefits for individual units, this BMP is often applied as pretreatment for other BMPs. In addition, oil/grit separators can enhance the long-term functionality of other BMPs with proper maintenance and non-exceedence of design loads. Refer to figures 1 through 3 for schematics of typical oil/grit separator system components.

Considerations

Such systems should only be applied to small drainage areas (one acre limit) and in tandem with other BMPs, since quantity and quality control are greatly limited when used alone. It is important to note that any runoff exceeding the design limits should be allowed to bypass the system. In addition, units must be both watertight, in order to prevent possible groundwater

Purposes

	Water Quantity
Flow attenuation	N/A
Runoff volume reduction	N/A
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	□
Nitrogen (N)	□
Heavy Metals	□
Floatables	■
Oil and grease	■
Fecal coliform	□
Biochemical Oxygen Demand (BOD)	□

contamination, and, in below grade systems, properly reinforced. Maintenance is frequently required since proper performance relies upon it.

Design Guidelines

For specific design instructions, see the provided list of resources. Grit chambers typically consist of a forebay, a separator section, and an afterbay. The following general components should be achieved when designing such a system:

- Runoff enters the forebay, which contains a permanent pool of water (minimum four foot depth), and provides pollutant removal via filtering and sedimentation;
- Stormwater enters the separator section, through screened orifices, providing for immiscible separation;
- Stormwater passes through a bottom opening of an inverted pipe to the afterbay, located above the chamber floor, where further settling and ultimate discharge occur.

To achieve consistent removal of pollutants, the volume of the permanent pools should be maximized, with a cumulative permanent pool volume of at least 400 cubic feet per acre of contributing impervious area. Additional vertical baffles, located along the bottom of the permanent pools can maximize settleability and minimize sediment resuspension.

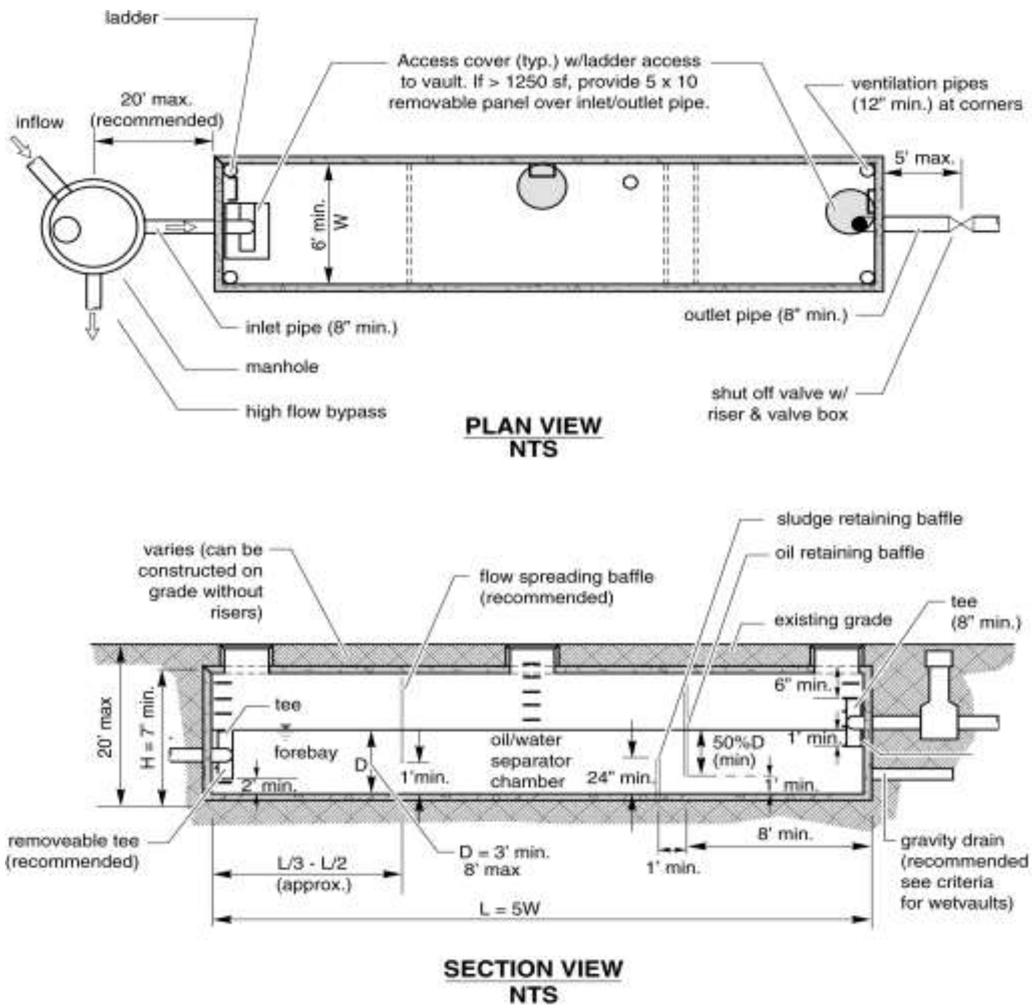


Figure 16: Schematic of a Typical Grit Chamber (Cited by Barr Engineering, Co., 2003; Source: Washington Department of Ecology, 1999)

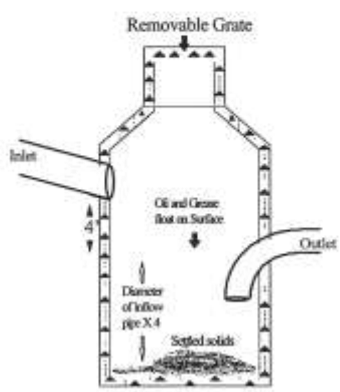


Figure 17: Schematic of a Typical Sump Catch Basin (Cited by Barr Engineering Co., 2003; Source: Massachusetts Department of Environmental Protection, 1997)

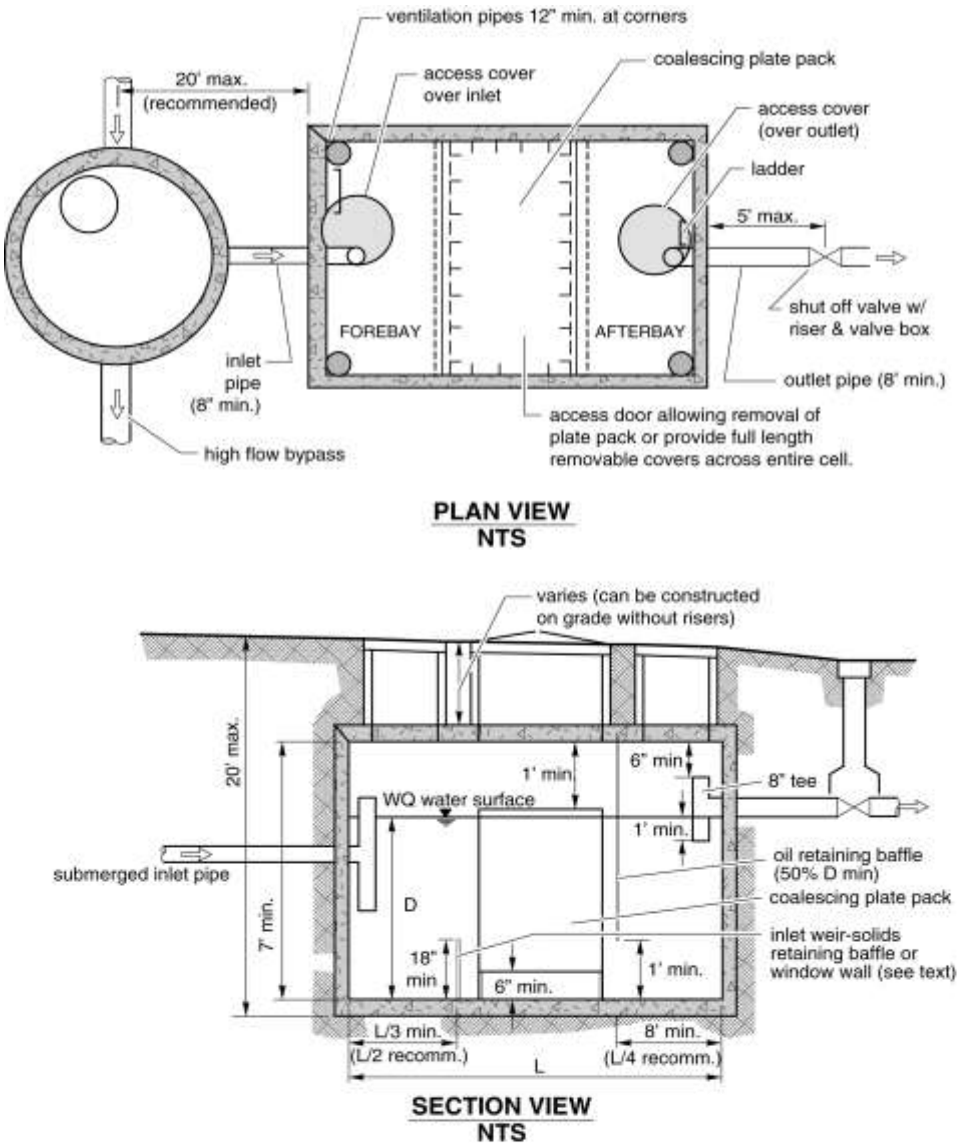


Figure 18: Schematic of a Typical Oil/Grit Separator (Cited by Barr Engineering, Co., 2003; Source: Washington Department of Ecology, 1999)

Maintenance Recommendations

Since such systems focus on removing contaminants, the removal of accumulated material is necessary to the BMP's life and functionality. As with other BMPs, failure is often attributed to lack of regular maintenance; therefore, maintenance considerations should include:

- Removal of contaminants every six months;
- Ideally, in areas of high sediment loading, check and clean after each major storm, with monthly inspections;
- Catch basin cleaning, via vacuum pumps, should be employed following confined space entry procedures, along with record-keeping of how much sediment was removed, in order to determine a routine cleaning schedule;

- Disposal of contaminants under the applicable state, local, and federal guidelines and regulations.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Oil/Grit Separators*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STDetOilGrit.pdf

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 8.1: Floatable Skimmer (aka. Oil/Water Separator).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/8.1fs.pdf

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Hydrodynamic Separators*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_hydro.pdf

U.S. EPA (2006, May). *Manufactured Products for Stormwater Inlets*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=79&minmeasure=5

Permeable Weirs

Potential Applications

This BMP is most often employed as a regional control measure for large drainage areas, although it can also be applied to smaller sites. Permeable weirs are designed for both water quantity and quality control measures, functioning much like a dry extended storage pond. Under low flow conditions, water is allowed to pond behind the structure and slowly discharge through the stack openings. Under high flow conditions, the water discharges through and over the structure. They are typically placed within either a low-quality wetland or a constructed water quality treatment pond.

Purposes

	Water Quantity
Flow attenuation	■
Runoff volume reduction	□
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	□
Nitrogen (N)	□
Heavy Metals	□
Floatables	◧
Oil and grease	□
Fecal coliform	□
Biochemical Oxygen Demand (BOD)	□

Brief Description

Permeable weirs are a relatively new concept and, as a result, provide little data regarding streamlining their application and/or design. The permeable weir is constructed of stacked, treated lumber, with long, narrow gaps between each timber to provide for slow release of collected stormwater. The main focus of this BMP is on water quantity control with some quality control provided, primarily via sedimentation of ponded stormwater runoff. For schematics concerning the typical application and suggested placement within a BMP treatment train, refer to figures 1 and 2 (located at the end of this document).

Considerations

As previously mentioned, this BMP has yet to be applied on a wide scale and, therefore, there are no reliable considerations. However, like other flow attenuation devices, separation of the bottom of the unit from the seasonally high groundwater table is recommended. In addition, removal of sediments and inspection of timber should be priorities to maintain design conditions.

Design Guidelines

For specific design instructions, see the provided list of resources. In general, gaps between the stacks should provide for complete discharge of the total volume resulting from a two year storm event, with the length and gaps providing for a detention time of 24 to 48 hours before fully draining to normal conditions. Additionally, a structural analysis is required, in order to ensure that overturning (failure) of the weir never occurs.

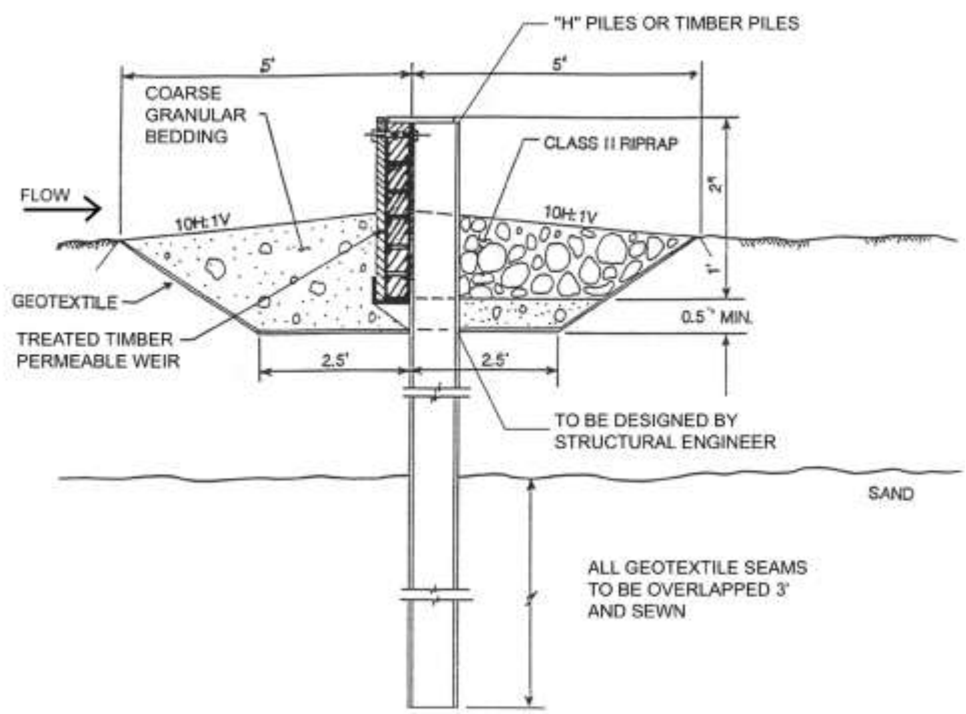


Figure 19: Typical Permeable Weir Cross Section Schematic (Cited by Barr Engineering, Co., 2003; Source: Klein, 1997)

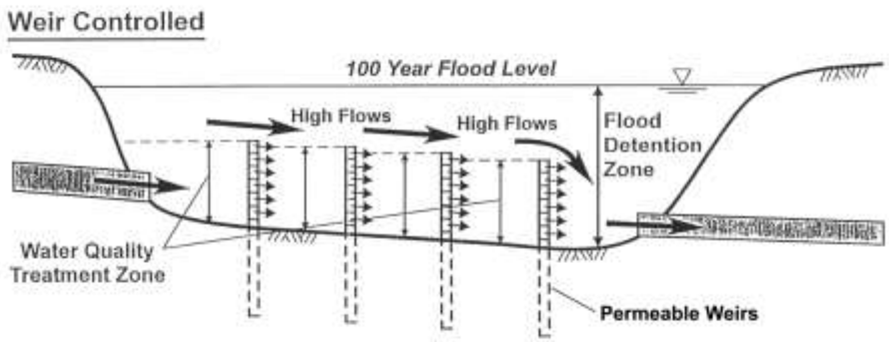


Figure 20: Schematic of a BMP Treatment Train Involving a Dry Pond and Permeable Weir Control (Cited by Barr Engineering, Co., 2003; Source: Klein, 1997)

Maintenance Recommendations

Since such systems focus on removing suspended contaminants, particularly sediments, the removal of settled material is necessary to the BMP's life and functionality. Therefore, the primary maintenance considerations should include:

- Regular inspection of timbers, noting any changes in the size of the gaps (due to swelling), which will alter the design discharge capabilities of the weir;
- Clogging must be accounted for and managed via regular sediment removal, in order to maintain adequate discharge;
- Sustaining healthy vegetation, as needed.

Regular maintenance requirements for the pretreatment basin include sediment, trash, and debris removal, as well.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Permeable Weirs*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STFlowPermWeir.pdf

Proprietary Flow Control Devices

Potential Applications

Such BMPs are employed to reduce the flow rate of stormwater being applied to downstream stormwater management structures or combined sewer systems. They are useful in retrofitting a clog-prone standpipe outlet, due to the ability to move sediments via a vortex pattern.

Brief Description

There are numerous proprietary flow control devices available, providing alteration of stormwater runoff flows. They typically serve as an outlet control, reducing stormwater flow rates through application to downstream stormwater BMPs. Such systems only provide water quantity control.

Considerations

For any device specific considerations, refer to the manufacturer.

Design Guidelines

For specific design guidelines, refer to the manufacturer.

Maintenance Recommendations

For specific maintenance recommendations, refer to the manufacturer.

Purposes

	Water Quantity
Flow attenuation	■
Runoff volume reduction	□
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	N/A
Total Phosphorous (TP)	N/A
Nitrogen (N)	N/A
Heavy Metals	N/A
Floatables	N/A
Oil and grease	N/A
Fecal coliform	N/A
Biochemical Oxygen Demand (BOD)	N/A

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Bioretention Systems*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STFlowProprietary.pdf

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 10.1: Proprietary Devices.* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/10.1.pdf

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 10.1.1 – 10.1.12.* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/BMP.aspx

Surface Sand Filters

Potential Applications

This off-line BMP is intended to address and service the spatial constraints of high-density, urban sites, which are notorious for small, highly impervious drainage areas, thus making larger BMP application unfeasible. They are effective where soils and groundwater concerns do not support infiltration devices and where first flush scenarios are prevalent. They primarily serve as quality control, with effective removal of suspended contaminants and moderate removal of bacteria; however, they are limited by poor dissolved contaminant and nutrient removal (U.S. EPA, 1999).

Brief Description

Sand filters successfully service spatially constrained, dense, urban sites, where contaminant loads (primarily particulates) are present. Focus is on water quality management as opposed to water quantity. Application is reliant on site criteria, including soils, evaporation rates, infiltration rates, and available space. Surface sand filters are most effective when used as part of a BMP treatment train, focusing on treating the first flush aspect of stormwater runoff resulting from urban drainage areas. For a schematic of a typical surface sand filter, see Figure 1 (located at the end of this document).

Considerations

Such systems should only be applied to small drainage areas (one to ten acres, less than five acres is preferable) that have been properly stabilized and will not clog the BMP, which requires a pretreatment component to ensure. In general, an elevation difference of four feet between the inlet and outlet is necessary. Additionally, it is recommended that a two

Purposes

Water Quantity

Flow attenuation

Runoff volume reduction

Water Quality

Pollution Prevention

Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A

Pollutant Removal

- Total Suspended Sediment (TSS)
- Total Phosphorous (TP)
- Nitrogen (N)
- Heavy Metals
- Floatables
- Oil and grease
- Fecal coliform

foot separation between the seasonally high groundwater table and the bottom of the BMP be maintained at all times.

For cold climates, such as Utah, this BMP has been linked to decreased performance as a result of frozen pipes and frozen underdrain systems (Barr Engineering Co., 2001).

Design Guidelines

For specific design instructions see the list of resources. From top to bottom, a surface sand filter is composed of sand, a geotextile, and an underdrain system. The following components should be considered when designing such a system (Barr Engineering Co., 2001; King County Department of Natural Resources, 1998):

- Pretreatment, serves to remove debris, solids, and oils (depending on the pollutants present), with a prescribed length to width ratio of 3:1 and depth of three to six feet;
- Inlet structures, serve to enhance distribution and slowing of the applied stormwater runoff flow;
- Energy dissipation device, serves to prevent gouging and aid in spreading of flow;
- Impermeable liner, necessary only if groundwater could be affected or if underflow could damage structures;
- Geotextile liner, necessary when an impermeable liner is not needed;
- Other considerations include an access ramp with a slope of less than 7:1 (allows for maintenance and entrance), side slopes of less than 3:1 (allows for mowing), and perimeter fencing (for safety).

Maintenance Recommendations

Since such systems focus on removing suspended contaminants, particularly sediments, the removal of settled material is necessary to the BMP's life and functionality. Therefore, the primary maintenance considerations include (SMRC, n.d.):

- Maintenance every six months to five years, depending on the watershed, in order to ensure functionality;
- Inspection after each major storm, during the beginning of its life, with inspections every six months thereafter;
- When drawdown time exceeds 20% of the design, removal and replacement of the top two to three inches of discolored sand, with rakes or low ground pressure equipment (if possible), under dry conditions is required;
- Sustaining healthy vegetation, as needed.

Regular maintenance requirements for the pretreatment basin include sediment, trash, and debris removal, as well.

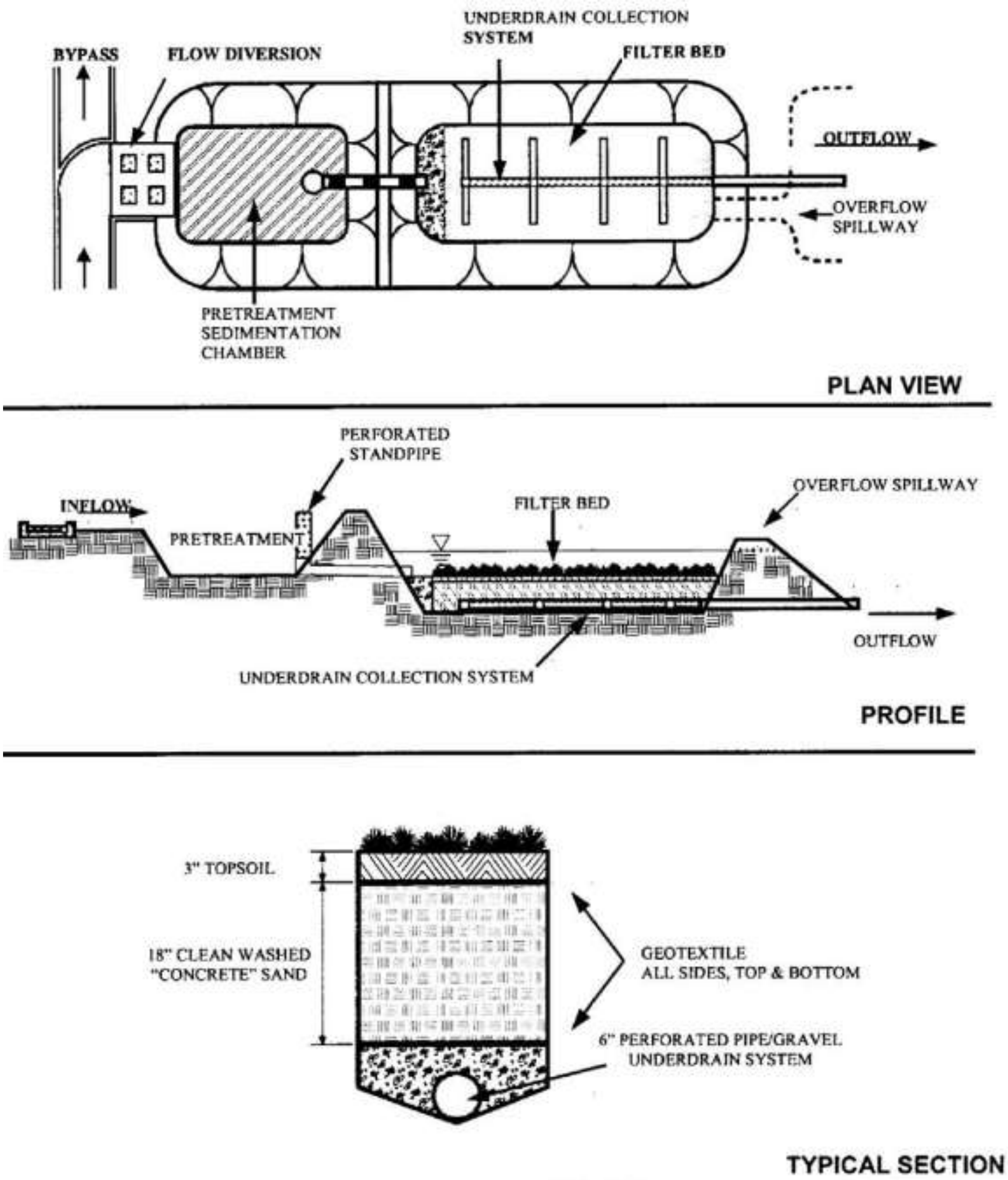


Figure 21: Schematic of a Surface Sand Filter (Source: SMRC, n.d.)

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Surface Sand Filters*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STFiltSurfSand.pdf

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

King County Department of Natural Resources (1998). King County, Washington, *Surface Water Design Manual*. Seattle.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Sand and Organic Filter*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Sand Filters*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_sandfltr.pdf

U.S. EPA (2006, May). *Sand and Organic Filters*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=73&minmeasure=5

Underground Filters

Potential Applications

Underground filters function best in small, urban drainage areas and are similar to the Surface Sand Filter BMP, the difference being that filter media and underdrain systems are installed below the grade, in a vault. This off-line BMP is intended to address and service the spatial constraints of high-density, urban sites, which are notorious for small, highly impervious drainage areas, thus making larger BMP application unfeasible. They are effective where soils and groundwater concerns do not support infiltration devices and where first flush scenarios are prevalent. They primarily serve as quality control, with effective removal of suspended contaminants and moderate removal of bacteria; however, they are limited by poor dissolved contaminant and nutrient removal.

Purposes

	Water Quantity
Flow attenuation	□
Runoff volume reduction	□
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy Metals	■
Floatables	■
Oil and grease	◧
Fecal coliform	◧
Biochemical Oxygen Demand (BOD)	◧

Brief Description

In general, underground sand filters can either be site specific or proprietary in nature. The former is typically composed of a three-chamber system:

- Pretreatment, such as a wet pool (temporary storage);
- Sand Filter, to spread flow (temporary storage);
- Collection basin for filtered runoff.

Underground filters have demonstrated effective removal of particulate contaminants and water quality improvement. Examples of proprietary devices include the D.C. Sand Filter, the Delaware Sand Filter, the Storm Filter, and the Hydro-Kleen, of which resources can be found in the references section. See Figure 1 for a schematic of a typical underground filter (UDFCD, 2010).

Considerations

Similar to surface sand filters, underground filters are prone to freezing and clogging; however, this can be remedied with the addition of a bypass system or via flow controls, such as weirs or an oversized pretreatment chamber (approximately 50% of the design treatment volume). On the other hand, underground filters are less susceptible to freezing than surface sand filters, which is notable for cold climates, such as Utah. Additionally, pretreatment components are essential in providing for capture of deicing materials (i.e. sand and salt). Concerning maintenance requirements, it is imperative that adequate filter access be provided (Barr Engineering Co., 2001).

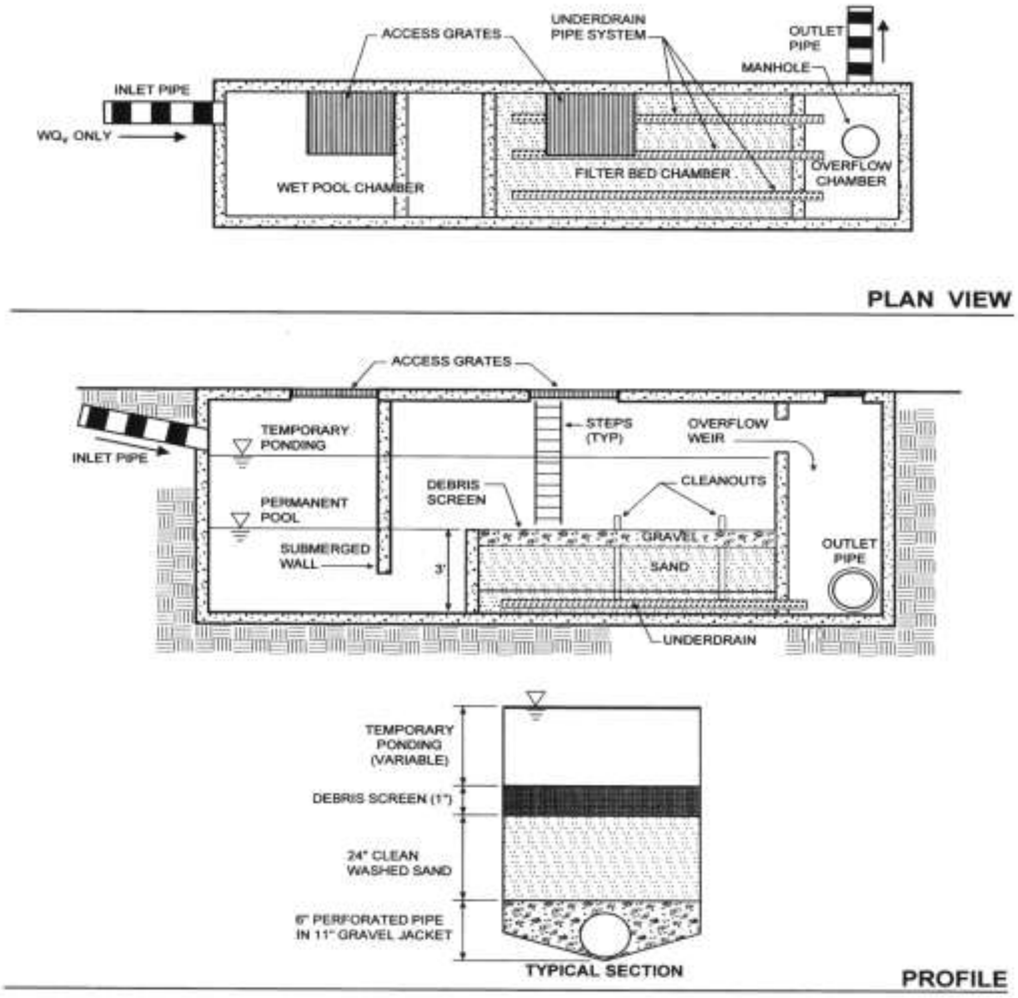


Figure 22: Schematic of an Underground Filter System, known as a "D.C. Sand Filter" (Cited by Barr Engineering, Co., 2003; Source: Maryland Department of the Environment, 1998)

Design Guidelines

For specific design instructions, please see the list of references and the general design considerations provided for the surface sand filters. In addition to the surface sand filter systems, underground filter systems require (Barr Engineering Co., 2001):

- Sediment storage within the presettling basin, typically one foot;

- A retaining baffle (if necessary for oil/floatables) in the presettling basin that extends one foot above and one foot below the design flow water level and is at least five feet horizontally from the inlet;
- Optimization of inlet flow distribution for minimal sand bed disturbance;
- Erosion protection (i.e. geotextile fabric) along the first foot of the sand bed adjacent to the inlet spreader;
- A dewatering gate valve;
- Removable panels over the entire sand bed;
- A geotextile fabric covering the entire sand bed;
- A minimum of 24 square feet of ventilation grate for each 250 square feet of sand bed surface area, to prevent anoxic conditions.

Maintenance Recommendations

Since such systems focus on removing suspended contaminants, particularly sediments, the removal of settled material is necessary to the BMP's life and functionality. Therefore, the primary maintenance considerations include:

- Maintenance every six months to five years, depending on the watershed, in order to ensure functionality;
- Inspection after each major storm, during the beginning of its life, with inspections every six months thereafter;
- When drawdown time exceeds 20% of the design, removal and replacement of the top two to three inches of discolored sand, with rakes or low ground pressure equipment (if possible), under dry conditions is required.

Regular maintenance requirements for the pretreatment basin include sediment, trash, and debris removal as well.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Underground Filters*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STFiltUnderground.pdf

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm

Cul-de-Sac Design

Potential Applications

This type of BMP is useful for both water quantity and water quality (when vegetated) management, via a reduction of the impervious surface area and the incorporation of vegetation. Impervious area can be minimized by

- Reducing the turning radius;
- Providing for a landscaped island area (see Figure 1);
- Using a T-shaped (hammerhead) turnaround (see Figure 1).

The addition of vegetation greatly enhances the treatability of this BMP, with a focus on dense-, deep-rooting perennial and native plants in place of traditional sod (Barr Engineering Co., 2001).

Purposes

Water Quantity

Flow attenuation

Runoff volume reduction

Water Quality

Pollution Prevention

Soil erosion

Sediment control

Nutrient loading

Brief Description

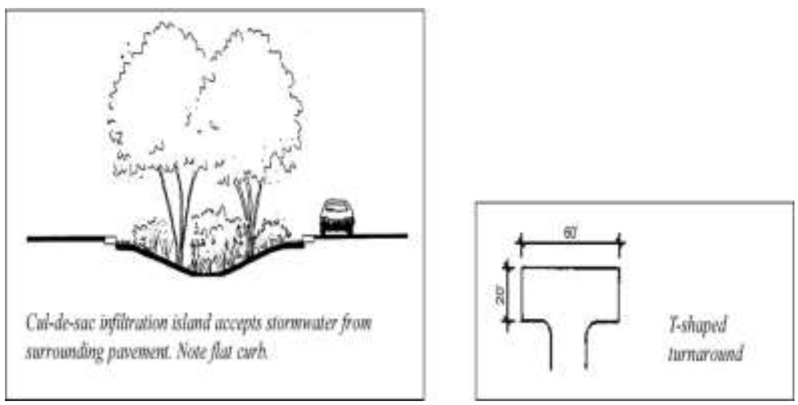
Focusing on cul-de-sac design allows for numerous preventative opportunities to reduce impervious surfaces, which has a positive impact on decreasing storm water runoff volumes and rates in addition to the potential contaminants. Typically accomplished through design and policy methods within residential areas. Secondary benefits include reductions in radiated and stormwater runoff temperatures, and enhanced aesthetics.

Considerations

Deep rooting vegetation (perennials and natives) provides greater stormwater runoff retention and treatability than shallow rooting sods. However, sustaining vegetation may entail additional irrigation and does require a committed, long-term maintenance and inspection plan. When minimizing impervious areas with cul-de-sacs, it is essential to always refer to the governing municipal guidelines and city ordinances (regarding small radii and emergency vehicles). Additionally, the number of homes will determine the extent of minimization (SMRC, n.d.).

Design Guidelines

To minimize impervious areas in an urbanized area, designers should consider: traffic volumes, number of homes, and city ordinances. Site drainage should be directed to the vegetated island, in order to capture and treat as much stormwater runoff as possible. For soils deemed unsuitable for proper infiltration, excavation and replacement with a plant soil mixture to a depth of three feet is



recommended. Vegetation greatly increases interception, infiltration, and evapotranspiration of stormwater runoff; however, water availability should be considered.

Maintenance Recommendations

During the vegetation establishment period (the first two to three years), monthly weeding of planted areas must be carried out. After sufficient establishment, weeding can be done once or twice per growth season. In colder climates, where snow accumulation is expected, plowing activities must collect snow away from swales and vegetated areas in order to prevent the detrimental accumulation of sands and salts.

References/Sources

Figure 23: Visual of infiltration island and T-shaped turnaround (Cited by Barr Engineering Co., 2003; Sources: Adapted from Schueler, 1995, and ASCE, 1990)

American Society of Civil Engineers (ASCE), National Association of Home Builders and Urban Land Institute. 1990. *Residential Streets.* Washington, D.C.

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Cul-de-Sac Design*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPImpCuldeSac.pdf.

Harris, Charles W. and Nicholas T. Dines. 1988. *Time-Saver Standards for Landscape Architecture.* McGraw-Hill, New York.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Schueler, Tom. 1995. *Site Planning for Urban Stream Protection.* Center for Watershed Protection, Silver Spring, MD.

Stormwater Manager's Resource Center, SMRC (n.d.). *Better Site Design Fact Sheet: Alternative Turnarounds*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Stormwater Manager's Resource Center, SMRC (n.d.). *Better Site Design Fact Sheet: Narrower Residential Streets*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

U.S. EPA (2006, May). *Narrower Residential Streets*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=72&minmeasure=5.

U.S. EPA (2006, May). *Alternative Turnarounds*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=90&minmeasure=5.

Valley Branch Watershed District. 2000. *Alternative Stormwater Best Management Practices Guidebook.* Lake Elmo, MN.

Green Rooftops

Potential Applications

This type of BMP is applied to rooftops on buildings ranging in size from small, residential garages to large, industrial structures. Substituting pervious cover for traditional, impermeable applications minimizes stormwater runoff volumes and rates. The presence of soil and vegetation enhances the water quality control aspect of this BMP, but should not be the sole reason for use as water quantity control is the main function.

Purposes

	Water Quantity
Flow attenuation	■
Runoff volume reduction	■

	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A

Brief Description

This BMP functions by managing stormwater via natural hydrologic methods. Vegetation serves to intercept, capture, and moderately treat rainwater, via root zone absorption, increased evapotranspiration, and attenuation of runoff to downstream environments. Categorized as either extensive (shallow substrate depth) or intensive (deeper substrate allowed) and applicability is solely dependent upon climate, structural and load bearing capacities, and budget.

Considerations

Prior to implementation and design, a thorough analysis of climate, characterization of precipitation events, rooftop environment, building structural and load-bearing capacities, plant selection, waterproofing, roof slope, and drainage or water storage systems should be carried out. In colder climates, such as Utah, the weight of snow may severely limit such applications. With extensive applications, access to rooftops may restrict ease of maintenance and, for both extensive and intensive, drought conditions possess potential fire hazards if left unkempt (Barr Engineering Co., 2001).

Design Guidelines

Analysis and design of green roofs should be carried out by a professional and/or engineer, as pre-application structural analysis is essential to safety. Once the roof structure and location have been verified as being able to support a green roof system, the roof surface must be waterproofed, with attention paid to joints, and tested. However, since conventional green roof systems are modular, design and construction can be accomplished by an outside source, with the necessary layers being provided for and include: waterproofing, moisture retention/drainage, soil selection, plant selection, and the optional irrigation system. For a basic visualization of green roof components, see Figure 1 (City of Chattanooga, Town of Signal Mountain, and Hamilton County, 2008; Barr Engineering Co., 2001).

Figure 24: Typical green roof cross section (Source: City of Chattanooga et al., 2008)

Maintenance Recommendations

During the vegetation establishment period, irrigation of plants is pivotal to overall survival and, therefore, should be applied regularly. However, after sufficient establishment, irrigation may not be necessary. Additionally, winterization of green roof systems may require replacement of most plants for the next growing season. Lastly, this BMP may require an annual survey ensuring a building's waterproof reliability (U.S. EPA, 2006).

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Green Rooftops*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPImpGreenRoof.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 9.6: Green Roofs (GR).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/9.6gr.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm.

U.S. EPA (2006, May). *Green Roofs*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=114&minmeasure=5.

Minimization of Land Clearing & Disturbance

Potential Applications

This BMP employs preventative techniques useful for both water quantity and water quality management via more streamlined methods of development. For instance, clearing should only predate active construction by a few months via implementation of a phasing plan for future developments.

This BMP should be applied to the earliest stages of all development plans, in order to minimize a site's contribution to degraded water resources, such as sediment runoff and erosion, due to a combination of increased runoff and sensitive land.

Brief Description

This customizable BMP focuses on preserving and protecting the natural spaces and processes by identifying and linking both on-site and off-site green infrastructure systems and natural features. This array of holistic, integrated design methods provides both quality and quantity control benefits, through enhanced environmental awareness and stewardship.

Considerations

Minimization of soil exposure area can be accomplished by developing a plan for construction phases, in addition to the necessary site controls, such as perimeter controls, sediment traps, basins, and diversions. This plan will provide for prioritization of disturbed areas within the vicinity of water bodies, wetlands, steep grades, and long slopes for effective stabilization within seven days of disturbance. It is important to consistently monitor the progress according to the outlined schedule and to make

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	◧
	Water Quality
Pollution Prevention	
Soil erosion	■
Sediment control	■
Nutrient loading	◧
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy Metals	□
Floatables	□
Oil and grease	□
Fecal coliform	□
Biochemical Oxygen Demand (BOD)	□

adjustments, as necessary, to ensure minimal disturbance of sensitive areas. Last, installation of protection devices (construction, fencing, flagging, and buffer zones) that prevent work area discharge prior to treatment and maintenance of work zone isolation from surrounding areas via delineation of wetland areas are necessary to successful site management.

Design Guidelines

This BMP is more focused on incorporating preventative pollution measures into the early design stages of proposed built environments, which include the following steps

- Carry out a pre-design, site sensitivity analysis;
- Preserve open space and minimize land disturbances;
- Protect sensitive natural features and natural processes;
- Identify and link both on-site and off-site green infrastructure systems;
- Incorporate natural features, such as wetlands, riparian corridors, and mature forests into site designs;
- Customize the site designs according to the site analysis.

Maintenance Recommendations

No maintenance recommendations exist for this BMP.

References/Sources

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

U.S. EPA (2006, May). *Preserving Natural Vegetation,* as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=34&minmeasure=4

U.S. EPA (2006, May). *Infrastructure Planning,* as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=86&minmeasure=5

U.S. EPA (2006, May). *Protection of Natural Features,* as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=126&minmeasure=5

Parking Lot Design

Potential Applications

This type of BMP is useful for both water quantity and water quality management, via a reduction of the impervious surface area and the incorporation of vegetation and infiltration swales. Impervious area can be minimized by:

- Reformatting municipal codes to reduce parking requirements;
- Minimizing stall dimensions;
- Promoting shared parking lots.

The addition of vegetation greatly enhances the treatability of this BMP, with a focus on dense-, deep-rooting perennial and native plants in place of traditional sod.

Brief Description

Focusing on parking lot design allows for numerous preventative opportunities to reduce impervious surfaces, which has a positive impact on decreasing storm water runoff volumes and rates in addition to the potential contaminants. The functionality of this BMP is typically accomplished through design and policy methods. Secondary benefits include shading of the impervious surface, reductions in radiated and stormwater runoff temperatures, and enhanced aesthetics.

Considerations

Deep rooting vegetation (perennials and natives) provides greater stormwater runoff retention and

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	■
	Water Quality
Pollution Prevention	
Soil erosion	□
Sediment control	◧
Nutrient loading	◧
Pollutant Removal (ONLY with Swales)	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy metals	◧
Floatables	◧
Oil and grease	◧
Fecal coliform	□
Biochemical Oxygen Demand (BOD)	□

treatability than shallow rooting sods; however, sustaining vegetation may entail additional irrigation and does require a committed, long-term maintenance and inspection plan. When minimizing impervious areas in parking lots, it is essential to always refer to the governing municipal guidelines.

Design Guidelines

To minimize impervious areas in an urbanized area, designers should consider: parking ratios, stall sizes, driving lane widths, and limitations of car types. Summer spillover sites should be identified and designed with pervious cover. Concerning site drainage, curb cuts, flat curbs, and maintaining the natural topography to aid in conveyance of runoff should be utilized to maximize capture. For soils deemed unsuitable for proper infiltration, excavation and replacement with a plant soil mixture to a depth of three feet is recommended. Vegetation greatly increases interception, infiltration, and evapotranspiration of stormwater runoff. Therefore, it is suggested that the mature canopy be able to cover 50% of the area, which may necessitate long-term irrigation.

Maintenance Recommendations

During the vegetation establishment period (the first two to three years), monthly weeding of planted areas must be carried out. After sufficient establishment, weeding can be done once or twice per growth season. If additional irrigation is required, especially during drought conditions, application should be limited to two inches per week. In colder climates, where snow accumulation is expected, plowing activities must collect snow away from swales and vegetated areas in order to prevent the detrimental accumulation of sands and salts.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Parking Lot Design*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPImpParking.pdf

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

Street Design

Potential Applications

This type of BMP is useful for both water quantity and water quality management. Impervious cover can be reduced by considering the following areas for improvement:

- Siting Streets;
- Street Width;
- Drainage Design.

Purposes

Water Quantity

Flow attenuation

Runoff volume reduction

Water Quality

Pollution Prevention

Soil erosion

Sediment control

Nutrient loading

Brief Description

Focusing on street design allows for numerous preventative opportunities to reduce impervious surfaces, which has a positive impact on decreasing storm water runoff and the associated contaminants.

Considerations

Siting Streets

In order to maximize storm water management (filtration and infiltration), municipalities should design based on preserving natural drainage patterns when possible and avoiding the placement of streets (and other impervious surfaces) in low-laying areas or atop highly permeable soils (unless a permeable pavement is considered).

Street Width

Many residential streets are wider than is necessary and should, therefore, be designed with the minimum width to provide support for the necessary traffic volume, on-street parking, and emergency, maintenance, and service vehicles.

Drainage Design

The traditional application of a curb-and-gutter system tends to amplify problems associated with storm water runoff volumes and velocities, in addition to discouraging infiltration and groundwater recharge. Therefore, curbless road design can be employed, through the use of roadside swales, in order to encourage infiltration. Additionally, on low-traffic streets without curbs, grass shoulders can provide an occasional parking lane and, therefore, reduce the paved area.

Design Guidelines

To minimize street widths in a suburban, residential area, designers can provide for only one parking lane, versus the traditional two, or provide for either one or no sidewalk (given an applicable, low traffic area). The following guidelines may be considered:

- Minimize pavement width, while still supporting the traffic volume, on-street parking requirements, emergency, maintenance, and service vehicles;
- Employ shallow, grassed roadside swales as opposed to the traditional curb-and-gutter system, when net densities are less than or equal to 6 to 8 units per acre;
- Swales designed to capture road storm water runoff should possess a slope no greater then 3:1;
- Limit sidewalks to one side of roads possessing less than 400 Average Daily Traffic (ADT), or 200 ADT for cul-de-sacs;
- Resist designing for distant future growth scenarios.

Figure 1 provides visual representation of standard and alternative options regarding street design.

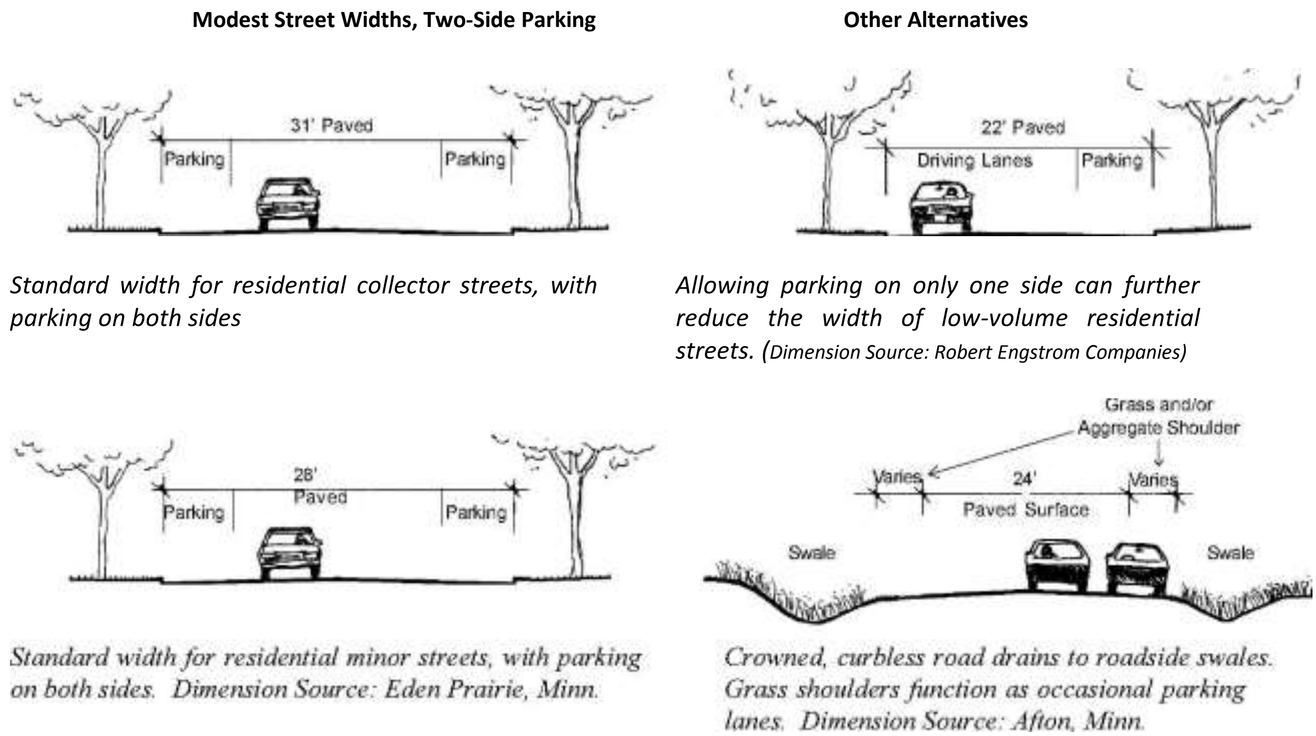


Figure 25: Different alternative options for street designs (Cited by Barr Engineering Co., 2003; Source: Valley Branch Watershed District, 2000)

Maintenance Recommendations

Swales vegetated by perennials, grasses, and wildflowers, as opposed to turfgrasses, must be weeded monthly (minimum) throughout the first two to three years. However, once establishment (two to three years) of the vegetation has occurred, weeding may only be required once or twice a growing season. Swales require periodic sediment removal in order to maintain volumetric and filtration functionalities.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Street Design*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPImpStreet.pdf.

Massachusetts Department of Environmental Protection. 1997. *Stormwater Management: Vol. 2.* Boston.

Prince George's County Department of Environmental Resources, Programs and Planning Division. 2000. *Low-Impact Development Design Strategies.* Largo, MD.

Schueler, Tom. 1995. *Site Planning for Urban Stream Protection.* Center for Watershed Protection, Silver Spring, MD.

U.S. EPA (2006, May). *Street Design and Patterns*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=128&minmeasure=5.

Valley Branch Watershed District. 2000. *Alternative Stormwater Best Management Practices Guidebook.* Lake Elmo, MN.

Turf and Porous Pavers

Potential Applications

This type of BMP is useful for primarily water quantity control, but possesses preventative water quality management as well, via a reduction of the impervious surface area and reconnecting the impervious areas with the natural, hydrologic cycle.

Present as modular paving blocks or grids, cast-in-place concrete grids, and soil enhancement technologies, which may **not** be appropriate for year-round use (groundwater and cold climate potentials), in heavily trafficked areas, or near stormwater hotspots. Urban applications commonly involve roadside right-of-ways, emergency access lanes, delivery access routes, and overflow parking areas. Residential surfaces, such as driveways and sidewalks, hold high promise for such BMPs as well.

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	■

	Water Quality
Pollution Prevention	
Soil erosion	□
Sediment control	◧
Nutrient loading	◧

Brief Description

Altering the material used to overlay an area allows for numerous preventative opportunities to reduce impervious surfaces, which has a positive impact on decreasing storm water runoff volumes and rates in addition to the potential contaminants. Typically accomplished through better site design methods. Secondary benefits include reductions in radiated and stormwater runoff temperatures and groundwater recharge. Additionally, as a result of decreased site runoff, less downstream stormwater management techniques are required and, therefore, will result in savings (Barr Engineering Co., 2001).

Considerations

Traffic volumes, typical vehicle loads, snowplowing activities, in-situ soil types, and (seasonally high) groundwater tables should all be considered prior to application. Handicapped access can also be limited by such practices. In cold climates, such as Utah, the potential for freeze-thaw damage is much higher if a system is not designed correctly (Barr Engineering Co., 2001).

Design Guidelines

First, an analysis of the site's soil type, land characteristics, topography, and groundwater levels must be carried out, which will decide applicability and, if appropriate, the subsequent design. The BMP consists of a subbase depth, which provides for the storage of the infiltrated stormwater, and will be controlled by in-situ soil permeability if not equipped with an underdrain system. These characteristics are of great importance to the longevity of the BMP, since water cannot be allowed to pool within the paved layer. In addition, there should be maintained a separation between the bottom of the subbase layer and the seasonally high groundwater table mark, in order to ensure no groundwater contamination will occur. Salt- and drought- tolerant vegetation should be applied to paver applications. For general cross sections of porous pavement and permeable interlocking concrete pavement (PICP) applications, see Figure 1 and Figure 2 (City of Chattanooga, Town of Signal Mountain, and Hamilton County, 2008).

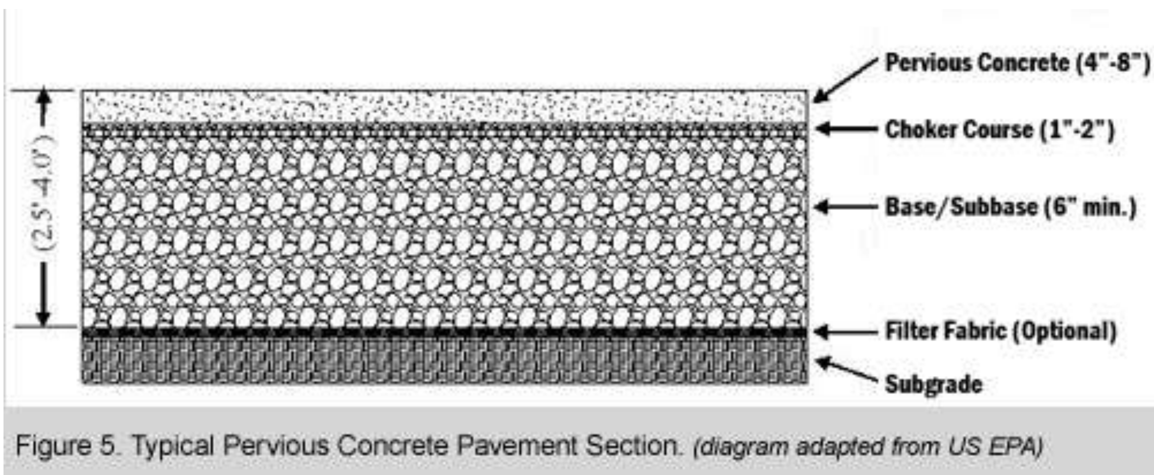


Figure 26: Typical Pervious Concrete Cross Section (Source: U.S. EPA, 2006)

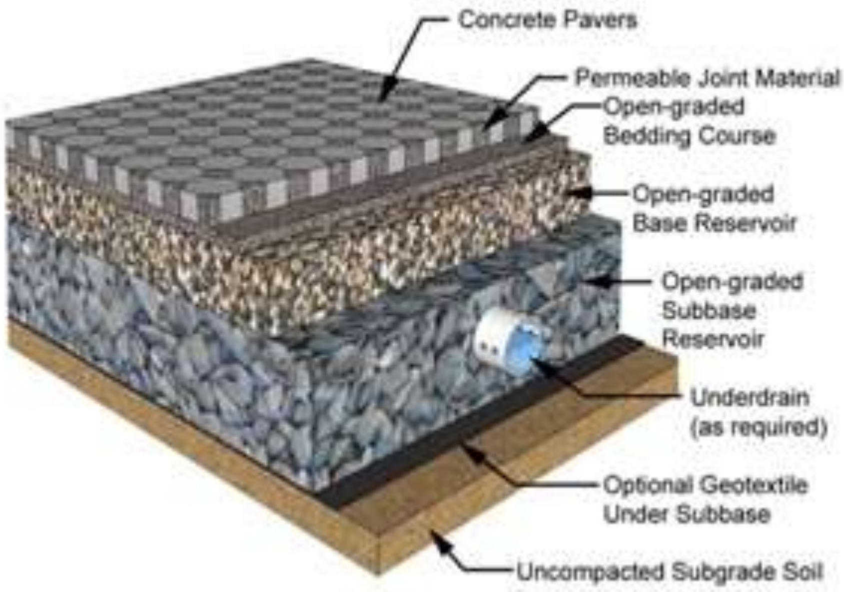


Figure 2: PICP Cross Section (Cited by U.S. EPA, 2006; Source: ICPI, 2000)

Maintenance Recommendations

For paver applications, regular maintenance of vegetation is required, including mowing, irrigation, and fertilization; however, fertilization possesses the potential for nutrient loading and should be done under extended dry-weather conditions. Cleaning out of the porous pavement void spaces should be done annually, prior to spring runoff, in order to retain efficiency and functionality of the system. In colder climates, where snow accumulation is expected, plowing activities require proper equipment alterations (i.e. skids) to protect the vegetation and pavement surface.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Turf Pavers*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPImpTurfPaver.pdf

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 9.8: Porous Pavement (PoP).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/9.8pop.pdf

Interlocking Concrete Pavement Institute (ICPI), Permeable Interlocking Concrete Pavements - Design, Specification, Construction, Maintenance, Third Edition, 2000

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Porous Pavement*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/

U.S. EPA (2006, May). *Pervious Concrete Pavement*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=137&minmeasure=5

U.S. EPA (2006, May). *Porous Asphalt Pavement*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=135&minmeasure=5

U.S. EPA (2006, May). *Pervious Interlocking Concrete Pavement*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=136&minmeasure=5

U.S. EPA (2006, May). *Green Parking*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=89&minmeasure=5

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm

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Animal Management

Potential Applications

This BMP focuses on water quality improvement by coordinating efforts of animal waste control (primarily from geese and dogs) within impacted watersheds. In doing so this helps minimize secondary consequences, such as lowered dissolved oxygen levels, fish kills, algae production, and pathogen-impacted (bacteria and viruses) waters.

Brief Description

Focused on pollution prevention, this BMP combines habitat modifications with no-feeding ordinances as first steps to dissuading goose populations. Controlling animal waste reduces nutrient loading in water bodies, thereby aiding in algal bloom and water quality control.

Considerations

Concerning goose control tactics, federal, state, or local permits may be required.

Design Guidelines

The following management practices can be implemented to decrease geese populations:

- No-feeding ordinances;
- Scare tactics;
- Habitat modifications (changes in vegetation and management);
- Goose barriers and repellents;
- Use of trained dog patrols;
- Goose population relocation;
- Lethal techniques, including addling eggs, sterilizing geese, hunting birds, or euthanization.

Purposes

	Water Quantity
Flow attenuation	N/A
Runoff volume reduction	N/A
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	■
Pollutant Removal	
Total Suspended Sediment (TSS)	N/A
Total Phosphorous (TP)	N/A
Nitrogen (N)	N/A
Heavy Metals	N/A
Floatables	N/A
Oil and grease	N/A
Fecal coliform	N/A
Biochemical Oxygen Demand (BOD)	N/A

Coordinating dog and pet waste management practices with pet owners, including dog ordinances, will increase positive impacts on water quality.

The design of a physical barrier around a water body will depend largely upon cost and what landowners/users find aesthetically pleasing. Such a barrier is similar to a buffer zone.

Maintenance Recommendations

The community animal ordinances may need to be modified over time to better address problems as they evolve. Artificial barriers require little maintenance and, if needed, are repaired easily. Any costs incurred will be in mowing and vegetation upkeep.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Animal Management*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPHousAnimal.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

U.S. EPA (2006, May). *Pet Waste Management*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=4&minmeasure=1.

BMP Maintenance

Potential Applications

All BMPs require periodic maintenance to sustain and enhance their performance. This section summarizes some of the general maintenance actions for the BMPs given in this appendix (see individual BMPs for in-depth details), as well as routine maintenance that should be applied to all existing devices, such as catch basins and ditches.

Sediment removal applies to ponds, wetlands, and filtration systems, such as grit chambers and surface sand filters. If proper sediment removal is not undertaken, the result is reduced storage capacity, increased potential for short-circuiting, and greater prevalence of sediment resuspension. Removal of trash and floatables aids outlet structure functionality by preventing clogging and altered hydraulics, in addition to aesthetic enhancement.

Vegetative maintenance applies to constructed wetlands, filter strips, wet and dry swales, and bioretention systems. Practices, which differ between systems, include mowing, reseeding, resodding, and removal of detritus and dead plant material.

Brief Description

Maintenance schedules vary depending upon BMP location, surrounding land use, soils classifications, climate, and watershed characteristics. Some BMPs require maintenance, such as sediment removal, every two or three years, while others may not require removal for decades. Other measures may include trash and floatable removal and vegetative maintenance.

Considerations

Maintenance by-products, such as degraded sediments, must be disposed of according to the necessary local, state, and/or federal requirements and guidelines. For instance, removed sediments may meet the criteria of a hazardous waste and, therefore, must be dealt with accordingly. Other wastes, while not hazardous, may contain high organic and inorganic contaminants and must be handled in accordance with approved regulations.

Maintenance Recommendations

For a table containing the general, recommended BMP maintenance schedules, see Table 1.

Table 1: Recommended BMP Maintenance Schedules (Source: City of Chattanooga et al, 2008)

<table>
<tr><th>Type of Practice</th><th>Management Practice</th><th>Maintenance Activity</th><th>Schedule</th></tr>
<tr><td rowspan="5">Detention/ Retention Practices</td><td rowspan="3">Ponds/ wetlands</td><td>Cleaning and removal of debris after major storm events; (>2" rainfall)
Harvesting vegetation when a 50% reduction in the original open water surface area occurs
Repairing embankment and side slopes
Repairing control structure</td><td>Annual or as needed</td></tr>
<tr><td>Removing accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost</td><td>5-year cycle</td></tr>
<tr><td>Removing accumulated sediment from main cells of pond once 50% of the original volume has been lost</td><td>20-year cycle</td></tr>
<tr><td>Dry Ponds</td><td colspan="2">Same as above</td></tr>
<tr><td>Wetlands</td><td colspan="2">Same as above</td></tr>
<tr><td rowspan="3">Infiltration Facilities</td><td rowspan="2">Infiltration Trench</td><td>Cleaning and removing debris after major storm events; (>2" rainfall)
Mowing and maintaining upland vegetated areas
Sediment cleanout
Repairing or replacing stone aggregate
Maintaining inlets and outlets</td><td>Annual or as needed</td></tr>
<tr><td>Removing accumulated sediment from forebays or sediment storage areas when 50% of the original volume has been lost</td><td>4-year cycle</td></tr>
<tr><td>Infiltration Basin</td><td>Cleaning and removing debris after major storm events; (>2" rainfall)
Mowing and maintaining upland vegetated areas
Sediment cleanout</td><td>Annual or as needed</td></tr>
</table>

		Removing accumulated sediment from forebays or sediment storage areas when 50% of the original volume has been lost	3- to 5-year cycle
Filtration Practices	Sand Filters	Removing trash and debris from control openings Repairing leaks from the sedimentation chamber or deterioration of structural components Removing the top few inches of sand, and cultivation of the surface, when filter bed is clogged	Annual or as needed
		Cleaning out accumulated sediment from filter bed chamber once depth exceeds approximately 1/2", or when the filter layer will no longer draw down within 24 hours Cleaning out accumulated sediment from sedimentation chamber once depth exceeds 12 inches	3- to 5-year cycle
Filtration Practices (continued)	Dry Swales, Grassed Channels, Biofilters	Mowing and removing litter/debris Stabilizing eroded side slopes and bottom Managing nutrient and pesticide use Dethatching swale bottom and removing thatching Aerating swale bottom	Annual or as needed
		Scraping swale bottom and removing sediment to restore original cross section and infiltration rate Seeding or sodding to restore ground cover (use proper erosion and sediment control)	5-year cycle
	Filter Strips	Mowing and removing litter/debris Managing nutrient and pesticide use Aerating soil on the filter strip Repairing eroded or sparse grass areas	Annual or as needed
	Bioretention	Repairing erosion areas Mulching of void areas Removing and replacing all dead and diseased vegetation Watering plant material	Biannual or as needed
		Removing mulch and applying a new layer	Annual

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: BMP Maintenance*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPHousBMPMaint.pdf

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 12 – Maintenance Checklists.* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/BMP.aspx

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 12.1 - BMP Maintenance Guidelines and Inspection Checklists.* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/12.1.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Stormwater Manager's Resource Center, SMRC (n.d.). *STP Maintenance Resources.* Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm.

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Visual Inspection*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_visnspct.pdf.

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Record Keeping*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_rcrd.pdf.

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Internal Reporting*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_intrnlrp.pdf.

U.S. EPA (1999, September). *Storm Water O&M Fact Sheet: Catch Basin Cleaning*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_catchbas.pdf.

U.S. EPA (2006, May). *BMP Inspection and Maintenance*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=91&minmeasure=5.

Pavement Management

Potential Applications

This BMP focuses on streets and parking lots with management appropriate for areas of five acres or less. These are significant sources for runoff pollutants, including suspended solids, phosphorous, zinc, copper, hydrocarbons, and fecal coliforms. The three main prevention applications provided are sweeping, alternative products and application rates, and other preventative measures.

Brief Description

Since impervious surfaces, such as parking lots, are a significant source of contaminants, pavement management practices can provide significant benefits regarding stormwater runoff quality. This BMP is strictly focused on quality control with no quantity control aspects provided.

Considerations

Target sites for the discussed applications must be five acres or less. Additionally, water quality benefits are highly dependent on the timing, frequency, and magnitude of pavement management procedures.

Design Guidelines

Sweeping

When properly designed and implemented, sweeping programs can significantly reduce street and parking lot contributions to pollutant loads, being most effective for

Purposes

	Water Quantity
Flow attenuation	N/A
Runoff volume reduction	N/A
	Water Quality
Pollution Prevention	
Soil erosion	N/A
Sediment control	■
Nutrient loading	■
Pollutant Removal	
Total Suspended Sediment (TSS)	■
Total Phosphorous (TP)	■
Nitrogen (N)	◧
Heavy Metals	■
Floatables	■
Oil and grease	■
Fecal coliform	■
Biochemical Oxygen Demand (BOD)	■

coarse particles, leaves, and trash removal. The following aspects should be considered to make sweeping techniques more efficient:

- Timing, twice yearly in early Spring and Fall, with additional sweepings (mid-Summer), as necessary;
- Equipment, broom and vacuum sweepers provide large and fine particulate removal, respectively;
- Techniques, optimizing patterns to increase capture and minimize spills;
- Residual Material, reusing collected materials to provide second use.

Alternative Products and Application Rates

Consideration of alternative deicers and preemptive application of deicing materials can reduce salt loadings and materials costs, respectively. Additionally, proper storage and well-trained operators will provide for minimized losses. If sands are to be used, elimination of fine particles will make collection via sweeping much easier.

Other Preventative Measures

Important for cold climates that experience heavy snowfall, such as Utah, is snow storage. There is significant potential for pollution accumulation during cold months that is converted to rapid pollutant release as temperatures warm; thus, snow should be plowed and stored away from water bodies and direct drainage areas.

Maintenance Recommendations

Since such systems focus on removing suspended contaminants, particularly sediments, the removal of settled material is necessary to the BMP’s life and functionality. Therefore, the primary maintenance considerations should include:

- Regular inspection of timbers, noting any changes in the size of the gaps (due to swelling), which will alter the design discharge capabilities of the weir;
- Clogging must be accounted for and managed via regular sediment removal, in order to maintain adequate discharge;
- Sustaining healthy vegetation, as needed.

Regular maintenance requirements for the pretreatment basin include sediment, trash, and debris removal as well.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Pavement Management*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPHousPavement.pdf

Stormwater Manager's Resource Center, SMRC (n.d.). *STP Maintenance Resources.* Retrieved June 2, 2011, from http://www.stormwatercenter.net/

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm

U.S. EPA (2006, May). *Parking Lot and Street Cleaning*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=99&minmeasure=6

Aquatic Buffers

Potential Applications

Technically, this BMP is a form of conservation, functioning as an integral part of both the aquatic ecosystem and the urban forest. Aquatic buffers are typically applied along a shoreline, wetland, or stream where development needs to be restricted or prohibited.

Brief Description

This BMPs primary function is to physically protect and separate a stream, lake, or wetland from future development encroachment or disturbance. When properly designed, aquatic buffers can provide stormwater management and serve as a right-of-way during floods, sustaining the integrity of the ecosystems and habitats. The three types of buffers include:

- Water pollution hazard setbacks, which may create a potential pollution hazard to the waterway, are used to institute a buffer between the natural and built environments;
- Vegetated buffers, which are any number of natural areas that exist to divide land uses or provide landscape relief;
- Engineered buffers, which are specifically designed to treat stormwater before it enters a stream, shore, or wetland.

Considerations

For optimal stormwater treatment, the buffer should incorporate the three zone buffer system: a stormwater depression area that leads to a grass filter strip, in turn leading to a forest buffer. The first zone is designed to capture and store stormwater during smaller storm events and bypass larger storms directly into the channel. Stormwater captured within the depression can then be spread across a grass filter, designed for

Purposes

	Water Quantity
Flow attenuation	
Runoff volume reduction	
	Water Quality
Pollution Prevention	
Soil erosion	
Sediment control	
Nutrient loading	
Pollutant Removal	
Total Suspended Sediment (TSS)	
Total Phosphorous (TP)	
Nitrogen (N)	
Heavy Metals	N/A
Floatables	
Oil and grease	
Fecal coliform	N/A
Biochemical Oxygen Demand (BOD)	N/A

sheetflow conditions, for the water quality storm. Last, the forest buffer is designed to restrict any discharge of surface runoff to the stream (i.e. full infiltration of sheetflow). However, in doing so, a potential loss of developable land is incurred, public access to privately held stream buffer may be required of private land owners, excessive nuisance species may appear, and such BMPs place an additional demand on scarce local or state government resources. Additionally, buffers designed to capture urban generated stormwater runoff will require more maintenance if the first zone is designated as a bioretention/engineered depression area.

Design Guidelines

An effective buffer design should be based on 10 practical performance criteria that govern how a buffer is sized, delineated, managed, and crossed, including:

- Minimimum total buffer width (typically 100 feet);
- Three zone buffer system, see Figure 1 and Table 1;
- Mature forest as a vegetative target;
- Conditions for buffer expansion or contraction;
- Physical delineation requirements;
- Condtions where a buffer can be crossed;
- Integration of stormwater and stormwater management within the buffer;
- Buffer limit review;
- Buffer education, inspection, and enforcement;
- Buffer flexibility.

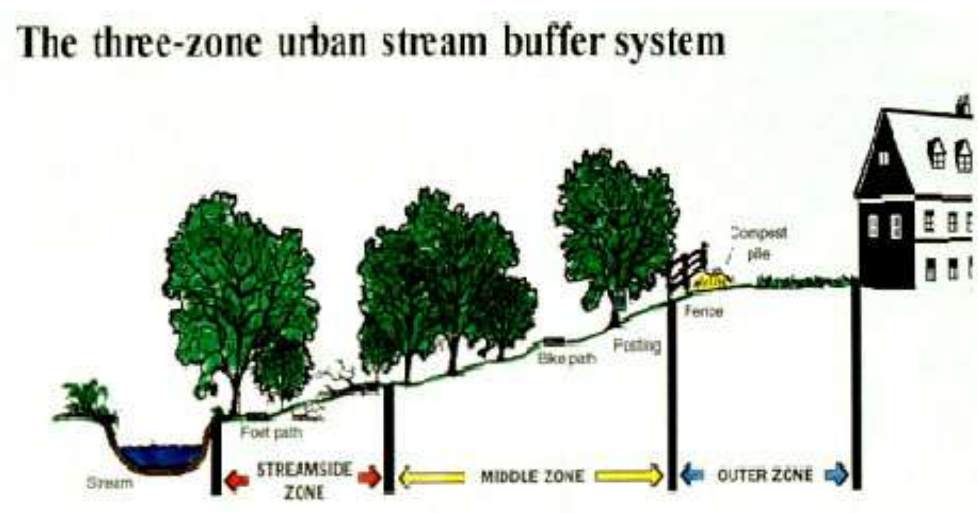

Figure 27: Three zone urban stream buffer system (Source: SMRC, n.d.)

Table 2: Three-zone urban stream buffer system characteristics descriptions (Cited by MSU, 1999; Source: NRCS, n.d.)

Characteristics	Streamside Zone	Middle Zone	Outer Zone
Function	Stream ecosystem's physical integrity is protected	Separation between upland development and streamside zone	Prevent encroachment and filter development runoff
Width	25 feet (minimum), plus wetlands and critical habitat	50-100 feet, dependent on stream order, slope, and 100-year floodplain	25 feet, minimum setback to structures
Vegetative Target	Undisturbed mature forest; reforest if grass	Managed forest, some clearing allowable	Forest encouraged; typically turfgrass
Allowable Uses	Extreme Restrictions (i.e. flood control, footpaths)	Restricted (i.e. some recreation, some stormwater BMPs, bike paths)	Unrestricted (i.e. residential uses, such as lawn, garden, compost, yard waste, most stormwater BMPs)

In order to provide maximum benefit via the aquatic buffer system, in terms of vegetation types (grass, shrub, and tree), Table 2 exhibits the level of benefit provided by each for numerous goals.

Table 3: Level of benefit associated with vegetation types: Grass, Shrub, and Tree (Cited by MSU, 1999; Source: NRCS, n.d.)

Benefit	Vegetation Type		
	Grass	Shrub	Tree
Bank erosion stabilization	Low	High	High
Sediment filtration	High	Low	Low
Nutrient, pesticide, and microbe filtration			
• Sediment-bound	High	Low	Low
• Soluble	Medium	Low	Medium

Aquatic habitat	Low	Medium	High
Wildlife habitat			
• Range/pasture/prairie wildlife	High	Medium	Low
• Forest wildlife	Low	Medium	High
Economic products	Medium	Low	Medium
Visual diversity	Low	Medium	High
Flood protection	Low	Medium	High

Maintenance Recommendations

An effective buffer management plan is required and should include: establishment, management, and distinctions of allowable and unallowable uses within the well-defined buffer zones.

References/Sources

Center for Sustainable Design, Mississipi State University, MSU (1999, December). *Water Related Best Management Practices in the Landscape – C. Stream Bank Protection and Restoration: Riparian Buffer Zone.* Prepared for the Watershed Science Institute, Natural Resource Conservation Service (NRCS). Retrieved June 2, 2011, from http://abe.msstate.edu/csd/NRCS-BMPs/pdf/streams/bank/riparianzone.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 9.2: Buffer Zone (BuZ).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/9.2buz.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Stormwater Manager's Resource Center, SMRC (n.d.). *Aquatic Buffers Fact Sheet: Buffer Zones*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool3_Buffers/BufferZones.htm.

Urban Drainage and Flood Control District, UDFCD (2010, November). *Urban Storm Drainage Criteria Manual Volume 3, Stormwater Best Management Practices.* Retrieved June 3, 2011, from http://www.udfcd.org/downloads/down_critmanual_volIII.htm.

U.S. EPA (2006, May). *Riparian/Forested Buffer*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=82&minmeasure=5.

Filter Strips

Potential Applications

This type of BMP is most effective at treating stormwater runoff generated from roads, highways, roof downspouts, and small parking lots. In addition, filter strips provide ideal conditions for both the outer zone of a stream buffer and as the pretreatment stage for other BMPs, such as filters and bioretention systems.

Brief Description

Characterized by densely vegetated, uniformly graded areas that treat sheet flow stormwater runoff resulting from adjacent surfaces. Function by slowing runoff velocities, trapping sediments and other contaminants, and providing some infiltration. Vegetation may include turfgrass (traditional), species native to the region, and trees and shrubs. Urban runoff studies have shown that a minimum removal rate of 35% of solids and 40% for nutrients can be expected for properly designed, constructed, functioning, and maintained systems. See Figures 1 and 2 for schematics of a vegetated filter strip.

Considerations

Maintaining sheet flow is imperative, as concentrated flows can disrupt the unit's treatability. This can be remedied by providing for sufficient grading and making sure site slopes are between 1% and 6%. Land scarcity is a major consideration, since filter strips require widths of at least 15 feet to be efficient and, therefore, are not viable retrofit options. Also, filter strips should not be used to remedy contaminant hot spots, due to the possibility for groundwater contamination and vegetation mortality.

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	◧
	Water Quality
Pollution Prevention	
Soil erosion	☐
Sediment control	◧
Nutrient loading	◧
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	☐
Nitrogen (N)	☐
Heavy Metals	☐
Floatables	◧
Oil and grease	◧
Fecal coliform	☐
Biochemical Oxygen Demand (BOD)	☐

Since filter strips do not provide for significant storage or infiltration, they are best applied in tandem with other BMPs.

Design Guidelines

Filter strips must never replace or damage natural environments, such as forested or natural areas, as these sites sufficiently mitigate any pollution resulting from stormwater runoff. In terms of width, the system must be at least 15 feet wide in the direction of flow in order to be effective; however, greater widths will increase treatment. For buffer areas, the Natural Resources Conservation Service (NRCS) recommends a minimum of 150 feet of separation between a land disturbance activity and a water body, which is dependent upon soil types and slopes. Additionally, the filter strip length should stretch the entirety of the impervious surface's length from which the stormwater runoff originates. Slopes of the filter strips should be no less than one percent and no more than six percent, to avoid ponding and concentrated flows, respectively. The top and toe of the slope should be as flat as possible, to encourage sheet flow and prevent erosion.

If application of concentrated flows is a possibility, the addition of a level spreader should be included to the design of the filter strip, which aids in spreading flow across the unit width.

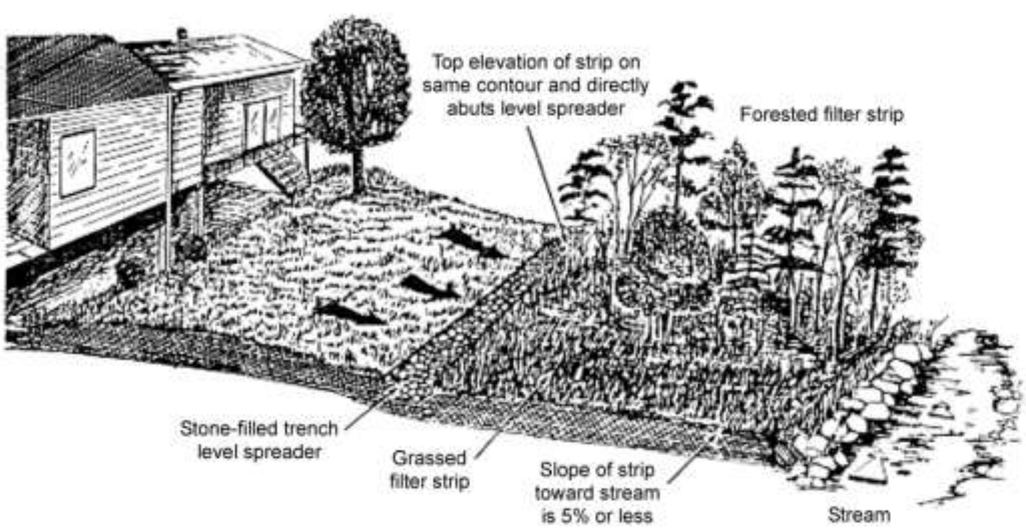

Figure 28: Filter Strip Incorporating Grassed and Wooded Areas (Cited by Barr Engineering, Co., 2001; Source: Claytor, 1996)

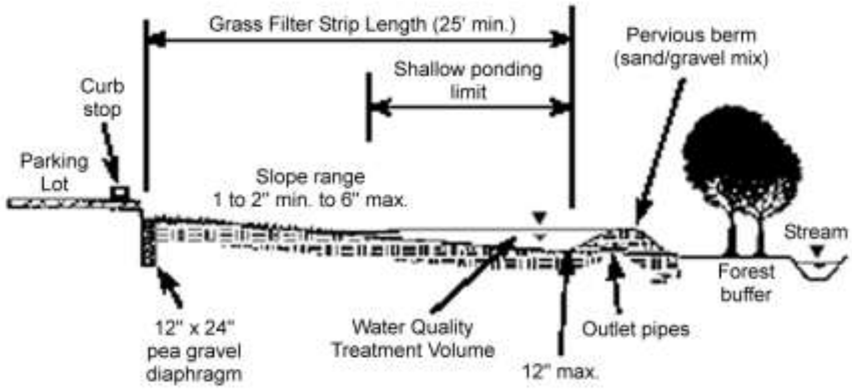

Figure 29: Profile View of a Filter Strip (Cited by Barr Engineering, Co., 2001; Source: Claytor & Schueler, 1996)

Maintenance Recommendations

Regular/Frequent

- Mowing of turfgrass with low ground pressure equipment to a height of three or four inches; cut only when soil is dry in order to prevent tracking damage to vegetation, soil compactions, and flow concentrations

Regular/Infrequent

- Removal of sediments and revegetation in areas of buildup
- Limit fertilizer applications, based on plant vigor and soil test results

Annual (Semiannual in the first year)

- Inspection of pea gravel diaphragm/level spreader for clogging and effectiveness, providing removal of collected sediments
- Inspection of unit for the presence of rills or gullies that may have formed due to concentrated flows and immediately fill with topsoil, install erosion control blankets, and either seed or sod the affected area
- Inspection of grasses, in order to ensure proper vegetation establishment, and, if not properly established, then prepare soil for reseeding or replacement with alternative species' and install erosion control blankets

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Bioretention Systems*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STFiltFilterStrips.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 9.5: Filter Strips and Swales (FSS).* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/bmps/9.5fss.pdf.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Grassed Filter Strip*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Sand and Organic Filter Strip*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

StormwaterPA (2006, December). *Pennsylvania Stormwater Best Management Practices Manual – Chapter 6: Structural BMPs: Vegetated Filter Strips*. Retrieved June 3, 2011, from http://www.stormwaterpa.org/6-4-9.html.

U.S. Department of Transportation Federal Highway Administration, U.S. DOT (n.d.). *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet – Filter Strips*. Retrieved June 3, 2011, from http://www.fhwa.dot.gov/environment/ultraurb/3fs11.htm.

U.S. EPA (2006, May). *Vegetated Filter Strip*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=76.

Water Environment Research Foundation, WERF (2009). *Using Rainwater to Grow Livable Communities: Sustainable Stormwater Best Management Practices: Stormwater BMPS: Filter Strips*. Retrieved June 1, 2011, from http://www.werf.org/livablecommunities/toolbox/filter.htm.

Landscape Design & Maintenance

Potential Applications

This BMP is site specific and aims to minimize the prevalence and effects of overapplication and misapplication of lawn fertilizers, which can cause nutrient loading problems in receiving water bodies. See the provided vegetation list for applicable plants.

Brief Description

This measure incorporates landscaping early in the stages of a site's design, in order to provide for a naturally diverse ecosystem. In doing so, this decreases the need for chemical controls, such as herbicides and pesticides. The main focus is on combining water quality and quantity control, with early stage incorporation of designs and continued maintenance, to provide pollution prevention, pollutant removal, and lessened magnitudes of site-related runoff.

Considerations

Landscaping functions most effectively when comprised of native vegetation, already adept at balancing and diversifying a site's ecological functions. The addition of plants will also encourage infiltration and help prevent erosion.

Design Guidelines

Select plants that are best adapted to a site's specific conditions, such as native vegetation, including: sun exposure, degree of moisture availability, and soil type. Proper vegetation will maximize BMP controls, thereby reducing the need for fertilizers and irrigation.

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	◧
	Water Quality
Pollution Prevention	
Soil erosion	■
Sediment control	◧
Nutrient loading	◧
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy Metals	◧
Floatables	◧
Oil and grease	◧
Fecal coliform	◧
Biochemical Oxygen Demand (BOD)	◧

Maintenance Recommendations

Lawn care is necessary to this BMPs long term functionality; therefore, a long-term maintenance plan should be established, providing for:

- Minimal fertilizer use and, if necessary, application of no-phosphorous fertilizer during cool, dry weather;
- Regular mowing to a 2.5 to 3.0 inch height, increasing height during summer, to minimize grass stress;
- Maximum irrigation of one inch per week, which promotes deep rooting behavior;
- Allowance of grasses to enter dormancy as a result of drought and winter conditions;
- Removal of plant debris, promoting community curbside collection programs, and education against sweeping debris into gutters can help minimize nutrient loading.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Landscape Design & Maintenance*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPHousLandscape.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 11: Landscaping References.* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/BMP.aspx.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Stormwater Manager's Resource Center, SMRC (n.d.). *The Practice of Watershed Protection - Section 6: Watershed Protection Tool #4 – Better Site Design*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/Library/Practice_Articles.htm#6.

U.S. EPA (2006, May). *Landscaping and Lawn Care*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=97&minmeasure=1.

Soil Erosion Control Management

Potential Applications

This BMP employs vegetative stabilization, via limiting vegetation clearing and reestablishment of vegetation in disturbed areas as quickly as possible. This BMP should be applied to all exposed soils that are not expected to be permanently stabilized with structures. Temporary seeding can also be employed, during construction practices, to minimize the disturbed area prone to erosion.

Brief Description

Vegetation protects the soil from erosion by raindrops, runoff, water currents, and wind. Plants provide interception of water, uptake of water, and improved soil infiltration and permeability. As vegetation is removed and soils are disturbed (via either compaction or erosion), the volume of stormwater runoff increases. Vegetative cover also modifies the soil microclimate by reducing variations in soil and air temperature and moisture content, thereby reducing aggregate breakdown of the soil.

Considerations

Vegetative cover is composed of two, distinct systems: the root structure and the aboveground vegetative canopy. The root layer enhances soil structure and stability, in addition to improving soil infiltration and permeability. The aboveground layer provides evapotranspiration, interception, and aids in moderation of the hydrologic cycle. Therefore, plant selection should be native and site-specific, in order to maximize benefits. However, such methods should not be employed during off-season, when heavy mulching is preferred (Price and Karesh, 2002).

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	◧
	Water Quality
Pollution Prevention	
Soil erosion	■
Sediment control	■
Nutrient loading	◧
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy Metals	□
Floatables	□
Oil and grease	□
Fecal coliform	□
Biochemical Oxygen Demand (BOD)	□

Design Guidelines

The first step in soil erosion control design is to decide how vegetation will be applied, following the subsequent general steps:

- Seeding, based on soils, moisture conditions, light levels, the probability of concentrated flows, land use, and maintenance level, which provides delayed erosion control;
- Sodding, which provides immediate erosion control, reduced chance of failure, fewer weed problems, and for use in areas where higher velocities make seeding impossible;
- Transplanting, which provides benefits similar to sodding, in addition to increased costs.

See the list of resources for the conditions necessary to successful vegetation implementation and establishment.

Maintenance Recommendations

The two main implementation strategies, seeding and sodding, require the following maintenance considerations (City of Chattanooga, Town of Signal Mountain, and Hamilton County, 2008; Barr Engineering Co., 2001):

- Seeded area soil moisture must be kept consistently moist (mulch aids in retention) for the first three weeks post-planting, to ensure growth;
- Mowing of non-native grasses should be carried out twice annually, to prevent establishment of woody plants;
- Mowing of native grasses (to a six inch height) should be carried out three times during the first year, to reduce invasive competition, once during the second year, and either burned or mowed every other year thereafter;
- Turf sod should be kept consistently moist for the first three weeks to ensure establishment and will require irrigation during drought conditions, or when dormancy is not required;
- Fertilization of sod should be carried out annually, with organic, non-phosphorous fertilizer, during spring or fall when rainfall is not expected within 14 days of application.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Soil Erosion Control: Vegetative Methods*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPSoilVeget.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 5 – Site Stabilization.* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/BMP.aspx.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Price, J.C. and Karesh, R. (2002, March). *Tennessee Erosion & Sediment Control Handbook: A Guide for Protection of State Waters through the use of Best Management Practices during Land Disturbing Activities.* Retrieved June 1, 2011, from http://www.state.tn.us/environment/wpc/sed_ero_controlhandbook/.

Stormwater Manager's Resource Center, SMRC (n.d.). *Erosion and Sediment Control Factsheets*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

Vegetative Stabilization

Potential Applications

This BMP focuses on the process of establishing vegetation, after seeding or sodding have taken place, in order to prevent on-site erosion. Establishment should occur as quickly as possible and provides a cheap, reliable method of erosion control.

Brief Description

Vegetation stabilization is a pollution prevention measure, aiming to reinforce site soils with the addition of native, hardy vegetation. Maintenance is important for vegetation in harsh climates, such as Utah (Barr Engineering Co., 2001).

Considerations

The two greatest challenges associated with vegetation establishment are extreme climates (i.e. cold or arid) and poor soil conditions. In arid conditions, drought-tolerant native species should be chosen, with the appropriate irrigation methods provided. In cold conditions, establishment is limited by the shortened growing season. Under poor soil conditions, soil amendments should be considered, including organic matter, fertilizers (with caution), and sulfur. Alternatively, healthy top soil can be imported to the site (U.S. EPA, 1999).

Design Guidelines

Establishment is reliant upon the maintenance recommendations provided. Following the suggestions will increase survival once plants have been implemented (as seed or sod). In addition, a

Purposes

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	◧
	Water Quality
Pollution Prevention	
Soil erosion	■
Sediment control	■
Nutrient loading	◧
Pollutant Removal	
Total Suspended Sediment (TSS)	◧
Total Phosphorous (TP)	◧
Nitrogen (N)	◧
Heavy Metals	□
Floatables	□
Oil and grease	□
Fecal coliform	□
Biochemical Oxygen Demand (BOD)	□

preliminary site soil test, to determine nutrient populations and if soil ammendations are required, may enhance plant growth and reduce the potential for nutrient pollution. Referral to conservation districts or extension offices can help apply or interpret these tests. For a population of viable vegetation alternatives, see the provided list in Appendix B.

Maintenance Recommendations

The process of vegetation establishment, especially under harsh conditions, requires the following maintenance considerations (Barr Engineering Co., 2001; City of Chattanooga, Town of Signal Mountain, and Hamilton County, 2008):

- Regular irrigation during establishment period, especially during drought conditions, in order to ensure survival of plants;
- Inspection of vegetation, providing for replacement of failed species, to best meet site conditions.

References/Sources

Barr Engineering Co. (2001, July). *Minnesota Urban Small Sites BMP Manual: Soil Erosion Control – Vegetative Methods*. Prepared for the Metropolitan Council. Retrieved June 2, 2011, from http://www.metrocouncil.org/environment/Watershed/bmp/CH3_RPPSoilVeget.pdf.

City of Chattanooga, Town of Signal Mountain, and Hamilton County (2008, January). *Stormwater BMP Manual: Best Management Practices, Section 5 – Site Stabilization.* Retrieved June 2, 2011, from http://www.hamiltontn.gov/waterquality/BMP.aspx.

International Stormwater Best Management Practices Database (n.d.). Cosponsored by the Water Environmental Research Foundation, American Society of Civil Engineers, Environmental and Water Resources Institute, Federal Highway Administration and U.S. Environmental Protection Agency. Retrieved June 3, 2011, from www.bmpdatabase.org.

Price, J.C. and Karesh, R. (2002, March). *Tennessee Erosion & Sediment Control Handbook: A Guide for Protection of State Waters through the use of Best Management Practices during Land Disturbing Activities.* Retrieved June 1, 2011, from http://www.state.tn.us/environment/wpc/sed_ero_controlhandbook/.

Stormwater Manager's Resource Center, SMRC (n.d.). *Stormwater Management Fact Sheet: Bioretention*. Retrieved June 2, 2011, from http://www.stormwatercenter.net/.

U.S. EPA (1999, September). *Storm Water Technology Fact Sheet: Vegetative Covers*. Retrieved June 3, 2011, from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_vegcvr.pdf.

U.S. EPA (2006, May). *Preserving Natural Vegetation*, as part of the National Menu of Stormwater Best Management Practices. Retrieved June 3, 2011, from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=34&minmeasure=4.